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Augmented Reality Media and Teacher Teaching Skills on Early Childhood Learning Outcomes: The Mediating Role of Motivation

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ABSTRACT

The motivational mechanisms through which Augmented Reality (AR) media and teacher teaching skills jointly influence early childhood learning outcomes remain empirically underspecified, particularly within the PAUD Indonesian context where contextually grounded evidence is scarce. This study examines the direct and indirect effects of AR media and teacher teaching skills on learning outcomes, with motivation specified as a formal mediating construct. A quantitative cross-sectional design was employed with 205 certified PAUD teachers drawn from various regions in South Sulawesi, Indonesia, recruited through purposive sampling. Data were analysed using PLS-SEM in SmartPLS 4.0, with significance assessed via bootstrapping across 5,000 subsamples. The measurement model demonstrated acceptable reliability (Cronbach's α: 0.815–0.836), convergent validity (AVE: 0.576–0.604), and discriminant validity confirmed through HTMT ratios ranging from 0.723 to 0.822, each below the 0.90 threshold. AR media was significantly associated with both motivation ($\beta = 0.438$, $p < 0.001$) and learning outcomes ($\beta = 0.329$, $p = 0.001$). Teacher teaching skills significantly predicted motivation ($\beta = 0.483$, $p < 0.001$) and learning outcomes ($\beta = 0.440$, $p < 0.001$). Motivation was the strongest direct predictor of learning outcomes ($\beta = 0.539$, $p < 0.001$), partially mediating both the AR learning outcomes and teacher skills–learning outcomes relationships. These findings suggest that instructional quality whether technological or human must first activate motivational engagement to produce measurable learning outcomes. PAUD institutions are encouraged to develop teacher competency and AR infrastructure concurrently, with motivational quality as a key process indicator of instructional effectiveness.

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INTRODUCTION

The integration of technology into early childhood education has accelerated considerably in the post-pandemic era, yet fundamental questions about which technologies meaningfully enhance learning outcomes and through what mechanisms remain insufficiently resolved. Augmented Reality (AR) has emerged as one of the most promising instructional technologies of the past decade, capable of superimposing interactive digital objects onto real-world environments through mobile devices. Its visual and kinaesthetic affordances align with the developmental characteristics of young learners, for whom abstract symbolic instruction is developmentally inappropriate (Piaget, 1952). Despite this theoretical fit, empirical evidence examining AR's effects within Pendidikan Anak Usia Dini (PAUD) remains fragmented, with few studies conducted in Southeast Asian settings where resource constraints, teacher preparation levels, and technological infrastructure differ substantially from Western contexts.

Two persistent gaps motivate the present investigation. First, the majority of AR-in-education studies focus on K-12 or higher education populations, leaving early childhood educators underrepresented in the literature (Akçayır & Akçayır, 2017; Cai et al., 2020). Second, prior research has examined the effects of AR media and teacher teaching skills on learning outcomes in isolation, rarely investigating the motivational mechanisms through which these inputs operate. Motivation functions as a critical mediating pathway transmitting instructional influence into measurable cognitive gains (Ryan & Deci, 2000; Schunk & DiBenedetto, 2020) a pathway whose omission produces an incomplete picture of what drives learning in technology-enriched early childhood classrooms.

The present study addresses these gaps through Partial Least Squares–Structural Equation Modeling (PLS-SEM) analysis of data collected from 205 certified PAUD teachers across Indonesia. The analytical framework is appropriate given the exploratory nature of the mediation hypotheses and the reflective measurement structure of the constructs involved (Hair et al., 2019; Ringle et al., 2012). The structural model simultaneously examines: (1) the direct effect of AR media on motivation and learning outcomes; (2) the direct and indirect effects of teacher teaching skills on motivation and learning outcomes; and (3) the mediating role of motivation between each instructional input and learning achievement. Based on the theoretical framework and identified gaps, the following hypotheses are proposed:

H1: AR instructional media has a significant positive effect on motivation.
H2: AR instructional media has a significant positive effect on learning outcomes.
H3: Teacher teaching skills have a significant positive effect on motivation.
H4: Teacher teaching skills have a significant positive effect on learning outcomes.
H5: Motivation has a significant positive effect on learning outcomes.
H6: Motivation mediates the relationship between AR media and learning outcomes.
H7: Motivation mediates the relationship between teacher teaching skills and learning outcomes.

This study makes three principal contributions. Theoretically, it extends Self-Determination Theory (Ryan & Deci, 2000) and the Technology Acceptance Model (Davis, 1989). into the early childhood domain by specifying motivation as a formal mediator within a technology-enhanced instructional framework. Methodologically, it employs PLS-SEM with bootstrap resampling to rigorously test mediation effects, addressing calls for greater methodological rigour in early childhood education research (Hamre et al., 2013). Empirically, it provides context-specific evidence from the Indonesian PAUD sector a rapidly expanding yet underserved population in the global early childhood research agenda.

Literature Review

The intersection of educational technology and early childhood learning has attracted considerable scholarly attention, yet theoretical and empirical foundations in this domain remain uneven. Three bodies of literature are directly relevant: (1) the pedagogical affordances of AR in formal learning environments; (2) the role of teacher teaching skills in shaping student outcomes; and (3) the motivational mechanisms mediating between instructional inputs and learning achievement.

Augmented Reality as an Instructional Medium

Augmented Reality distinguishes itself from other educational technologies through its capacity to blend physical and digital realities in real time, enabling learners to interact with three-dimensional, contextually embedded information rather than passive two-dimensional representations. Azuma, (1997) established the foundational boundaries of AR real-world integration, interactivity, and real-time processing that subsequent researchers have operationalised as design principles for instructional applications. Akçayır & Akçayır (2017), in a systematic review of 68 empirical studies, identified enhanced engagement and improved spatial understanding as the most consistently reported benefits of AR-based instruction, while noting that motivational outcomes remained among the least rigorously measured. Similarly, Cai et al.,

(2020) demonstrated that AR interventions in science education produced significant gains in conceptual understanding relative to conventional instruction, with younger learners showing the highest sensitivity to immersive visual scaffolding. Billinghurst & Duenser, (2012) further argued that AR's pedagogical value is contingent not on the technology itself but on the degree to which it reduces cognitive load while amplifying meaningful interaction with content a position resonant with Vygotskian perspectives on mediated learning, wherein the quality of the instructional tool determines its developmental impact (Vygotsky, 1980)

Within early childhood education specifically, the AR evidence base remains limited. Yilmaz, (2016) conducted one of the few controlled experiments involving AR with preschool-aged children, finding that AR-enriched storybooks significantly improved narrative comprehension and vocabulary retention relative to traditional picture books. Crucially, neither study examined motivation as a mediating construct, nor situated findings within the Indonesian PAUD context a gap the present investigation directly addresses.

Teacher Teaching Skills and Learning Outcomes

Parallel to the AR literature, substantial research has examined the role of teacher competencies in determining student achievement. Hattie (2012), in a landmark meta-analysis of over 800 meta-analyses, identified teacher quality as among the most powerful predictors of student learning, with effect sizes for specific pedagogical skills including instructional clarity, feedback quality, and classroom management consistently exceeding those of structural variables such as class size or school resources. In the early childhood domain (Hamre et al., 2013) developed the Classroom Assessment Scoring System (CLASS) to quantify teacher–child interaction quality, demonstrating that emotional support, classroom organisation, and instructional support each independently predict cognitive and language gains in preschool children, with scaffolding capacity emerging as a stronger predictor of school-readiness outcomes than either teacher qualifications or years of experience.

A persistent tension nonetheless runs through this literature: while teacher skills are consistently associated with student motivation and engagement, the precise mechanism through which pedagogical competence translates into measurable learning outcomes is rarely made explicit. Stronge, (2018) argued that effective teachers raise achievement not directly but by cultivating the conditions curiosity, persistence, and intrinsic interest that enable children to engage deeply with instructional content. This theoretical position implies that motivation is not merely a correlate of good teaching but a formal mediating pathway, a proposition the present study tests empirically within a technology-enhanced PAUD context.

Motivation as a Mediating Mechanism

The theoretical grounding for motivation-as-mediator draws principally from Self-Determination Theory (Ryan & Deci, 2000), which posits that motivation is maximally activated when three basic psychological needs autonomy, competence, and relatedness are satisfied by the learning environment. In the ECE context, AR media may fulfil the need for competence through immediate interactive feedback, while skilled teachers fulfil the need for relatedness through warm, responsive instructional interactions. These inputs collectively elevate intrinsic motivation, which drives the sustained cognitive engagement necessary for learning outcomes to materialise.

Empirical support for this mediational logic is accumulating. Schunk & DiBenedetto, (2020) concluded, across four decades of motivation research, that intrinsic motivation consistently mediates the relationship between instructional quality and academic achievement. Huang et al., (2019) demonstrated that perceived enjoyment a motivational variable fully mediated the effect of AR usability on learning performance among elementary students, confirming that AR's learning benefits are channelled through motivational responses rather than operating independently. Barak et al., (2011) similarly found that teachers' inquiry-based

instructional skills predicted student achievement only indirectly, through heightened intrinsic motivation and academic self-efficacy. These findings converge on a theoretically coherent proposition: in instructional environments combining technology integration with skilled pedagogy, motivation functions as the critical transmission mechanism between instructional inputs and learning outputs.

Identified Gap

Despite the theoretical plausibility of this mediational framework, no published study to the authors' knowledge has simultaneously modelled direct and indirect pathways from both AR media and teacher teaching skills to learning outcomes, with motivation as a formal mediator, within an early childhood education context in Southeast Asia. Existing studies examine these relationships in isolation, employ variable-centred approaches, or focus on older learner populations for whom the developmental logic of AR-supported motivation may operate differently. The present investigation fills this gap by constructing and testing a theoretically integrated structural model grounded in SDT, constructivist learning theory, and the technology-enhanced learning literature that positions motivation as the pivotal mechanism linking pedagogical and technological inputs to learning achievement in PAUD settings.

METHOD

This study adopts a postpositivist quantitative paradigm operationalised in contemporary social science by Creswell, (2009) , which holds that social phenomena including the relationship between instructional inputs and learning outcomes are governed by discoverable causal mechanisms that can be measured, modelled, and tested against empirical data, while acknowledging that measurement is inherently imperfect. This philosophical stance directly justifies the choice of Partial Least Squares–Structural Equation Modeling (PLS-SEM) as the analytical framework, which simultaneously estimates measurement error, latent construct relationships, and structural pathways within a single coherent architecture (Hair et al., 2019).

The research design is cross-sectional and correlational, employing a self-administered structured questionnaire to collect primary data from PAUD teachers across Indonesia. A cross-sectional design was appropriate given the study's objective of estimating structural relationships among stable dispositional constructs perceptions of AR media, teaching skill competency, motivational orientation, and learning outcomes at a single point in time. Longitudinal designs capable of establishing temporal precedence among the identified pathways are recommended for future research.

Sampling Strategy and Participant Criteria

Participants were recruited using purposive sampling, appropriate when the target population is defined by specific professional characteristics (Patton, 2002). Three inclusion criteria were applied: (1) active employment as a certified PAUD teacher at the time of data collection; (2) a minimum of one year of teaching experience in an early childhood setting; and (3) prior exposure to, or current use of, digital or technology-mediated instructional tools in classroom practice. Teachers with no prior experience of any educational technology were excluded, as they lacked the experiential referent necessary to respond meaningfully to AR-related items. The final analytical sample comprised 205 certified PAUD teachers drawn from various regions in South Sulawesi, Indonesia. (Hair et al., 2019), which requires a minimum sample of ten times the largest number of incoming paths to any single endogenous construct.

Tabel 1. Characteristics Respondent

Characteristic	Categories	n	%
Teaching Experience	1–5 yrs	72	35,1%
	6–10 yrs	89	43,4%
	>10 yrs	44	21,5%

Characteristic	Categories	n	%
Certification Status	Certified	158	77,1%
	Not Yet Certified	47	22,9%
Institution Type	Public	68	33,2%
	Private Foundation	94	45,8%
	Private Independent	43	21%
Educational Background	Bachelor's ECE	143	69,8%
	Bachelor's Non-Ed	38	18,5%
	Diploma	24	11,7%
Digital Technology Access	Adequate	127	62%
	Limited internet	55	26,8%
	Very limited	23	11,2%
AR Experience	Has used	88	42,9%
	Familiar	79	38,5%
	Unfamiliar	38	18,6%
		205	100%

As Hasil Belajar (HB) receives three incoming paths from M.AR, KG, and M the minimum threshold was 30 participants, substantially exceeded by the obtained sample. Statistical power was further verified using G*Power 3.1 (Faul et al., 2007) at the conventional threshold of $\alpha = 0.05$ with a medium effect size ($f^2 = 0.15$), confirming adequate power at 0.80.

To address the potential for common method bias a risk inherent in single-source, single-timepoint survey designs full collinearity VIF values were examined for all constructs prior to structural model estimation. All VIF values fell below the threshold of 3.3 recommended by (Kock, 2015), providing preliminary evidence that common method bias does not substantially distort the structural estimates reported below.

Instrumentation and Measurement Model

All four constructs Media Augmented Reality (M.AR), Keterampilan Guru (KG), Motivasi (M), and Hasil Belajar (HB) were operationalised using reflective measurement models, wherein observed indicators are conceptualised as imperfect manifestations of an underlying latent variable (Jarvis et al., 2003). Reflective specification is appropriate when indicators within a construct are interchangeable, highly correlated, and share a common latent cause conditions satisfied by the dispositional and perceptual nature of all four constructs (Henseler et al., 2016).

Each construct was measured using five Likert-scaled items anchored at 1 (Sangat Tidak Setuju) to 5 (Sangat Setuju), yielding a 20-item instrument. Item sources and adaptation procedures are as follows: M.AR items were adapted from the AR usability and engagement scales of (Huang et al., 2019) and (Cai et al., 2020), and reviewed by two early childhood technology specialists for contextual appropriateness within the Indonesian PAUD setting. KG items were drawn from the pedagogical competency framework of (Stronge, 2018) and localised to the Indonesian PAUD context through review by three certified early childhood education experts. Forward translation from English to Bahasa Indonesia was conducted by a bilingual education researcher, with back-translation verified by an independent translator to ensure semantic equivalence. Motivasi items were adapted from the Academic Motivation Scale Short Form (Vallerand et al., 1992) for the teacher-as-learner context, with wording adjusted to reflect PAUD instructional settings following expert panel review. HB items reflected teacher-reported learning outcome indicators aligned with the STPPA framework mandated by Indonesia's Ministry of Education and Culture. It is acknowledged that HB represents teacher-perceived rather than objectively measured child learning outcomes a conceptual boundary that is explicitly recognised as a study limitation.

Content validity for the full instrument was established through review by three subject-matter experts in early childhood education prior to pilot testing. A pilot study with 30 PAUD teachers drawn separately from the main analytical sample confirmed item clarity and preliminary reliability, with all item-level Cronbach's alpha values exceeding 0.70.

Analytical Procedure

Structural model estimation was conducted in SmartPLS version 4.0 (Hair et al., 2019) following the two-step analytical procedure recommended by (Hair et al., 2019): measurement model evaluation preceded structural model interpretation. Significance of structural paths was assessed via bootstrapping with 5,000 subsamples, generating empirical confidence intervals without distributional assumptions (Preacher & Hayes, 2008). Mediation was evaluated through the significance of indirect effects, with bootstrap confidence intervals excluding zero serving as the criterion for mediation support. Model fit was indexed by the Standardised Root Mean Square Residual (SRMR), with values below 0.10 considered acceptable for PLS-SEM (Henseler et al., 2016).

RESULTS AND DISCUSSION

Result

This section reports the findings of the PLS-SEM analysis conducted in SmartPLS 4.0, following the two-step procedure recommended by Hair et al., (2019): measurement model evaluation is completed and confirmed before structural model interpretation proceeds.

Tabel 2. Outer Loading

	Outer loadings
HB1 <- HB	0.759
HB2 <- HB	0.837
HB3 <- HB	0.702
HB4 <- HB	0.778
HB5 <- HB	0.710
KG1 <- KG	0.761
KG2 <- KG	0.744
KG3 <- KG	0.774
KG4 <- KG	0.794
KG5 <- KG	0.812
M.AR1 <- M.AR	0.811
M.AR2 <- M.AR	0.739
M.AR3 <- M.AR	0.755
M.AR4 <- M.AR	0.747
M.AR5 <- M.AR	0.752
M1 <- M	0.741
M2 <- M	0.715
M3 <- M	0.806
M4 <- M	0.785
M5 <- M	0.772

Table 2 presents the outer loadings for all 20 reflective indicators across the four constructs. Every indicator exceeded the minimum acceptable threshold of $\lambda \geq 0.70$ recommended by (Hair et al., 2019), with values ranging from 0.702 (HB3) to 0.837 (HB2). No indicator approached the upper redundancy boundary of 0.95, confirming that each contributes unique item-level variance to its respective construct. The M.AR construct produced the narrowest loading range (0.739–0.811), indicating homogeneous item content consistent with the unidimensional nature of technology perception scales. KG exhibited the highest peak loading (KG5 = 0.812), reflecting the strength of items tapping pedagogical responsiveness and adaptive instruction.

Table 3. Construct Reliability dan Validity

	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
HB	0.815	0.825	0.871	0.576
KG	0.836	0.840	0.884	0.604
M	0.823	0.830	0.875	0.585
M.AR	0.819	0.824	0.873	0.580

As reported in Table 3, all four constructs demonstrated strong internal consistency. Cronbach's alpha values ranged from 0.815 (HB) to 0.836 (KG), each exceeding the conventional threshold of $\alpha \geq 0.70$. Composite reliability estimates (rho_c: 0.871–0.884) corroborated these findings. The marginal superiority of rho_c over alpha is theoretically expected in reflective models where indicators are not assumed to be equally weighted (Dijkstra & Henseler, 2015).

Average Variance Extracted (AVE) values exceeded the (Fornell & Larcker, 1981) threshold of 0.50 for all constructs: HB = 0.576, KG = 0.604, M = 0.585, M.AR = 0.580, confirming convergent validity. KG returned the highest AVE (0.604), indicating that the pedagogical competency items share the greatest proportion of common variance attributable to the underlying latent construct.

Table 4. Fornell Lacker

	HB	KG	M	M.AR
HB	0.759			
KG	0.758	0.777		
M	0.845	0.837	0.765	
M.AR	0.808	0.810	0.829	0.761

Table 4 presents the Fornell-Larcker matrix. For most construct pairs, the square root of each construct's AVE (diagonal) exceeds its inter-construct correlations. However, a discriminant validity concern is noted for two pairs: the correlation between Motivasi (M) and Hasil Belajar (HB) (r = 0.845) exceeds the diagonal values for both HB ($\sqrt{AVE} = 0.759$) and M ($\sqrt{AVE} = 0.765$). Similarly, M.AR with M (r = 0.829) and KG with M (r = 0.837) approach or exceed their respective diagonal values. These patterns suggest partial overlap between constructs and are acknowledged as a measurement limitation of the present study.

Tabel 5. HTMT

	HB	KG	M	M.AR
HB				
KG	0.723			
M	0.820	0.819		
M.AR	0.801	0.802	0.822	

Table 5 reports the Heterotrait-Monotrait (HTMT) ratio as a more conservative and robust criterion for discriminant validity assessment, complementing the Fornell-Larcker criterion. All HTMT values fell below the recommended threshold of 0.90, ranging from 0.723 (KG–HB) to 0.822 (M.AR–M). Notably, the HTMT values for construct pairs that approached the Fornell-Larcker boundary including M–HB (0.820), M.AR–M (0.822), and KG–M (0.819) remain clearly below the 0.90 threshold, providing reassurance that the constructs are empirically distinct despite their theoretical proximity. These results confirm that discriminant validity is established across all construct pairs when assessed using the HTMT criterion, and that respondents adequately differentiated among the four measurement domains as theoretically intended.

Tabel 6. R-Square

	R-square	R-square adjusted
HB	0.752	0.748
M	0.767	0.765

The structural model was then assessed by examining the coefficient of determination (R-square). The results show that the R-square value for Motivation is 0.767, indicating that 76.7%

of the variance in motivation is explained by Augmented Reality Media and Teacher Skills. Meanwhile, the R-square value for Learning Outcomes is 0.752, meaning that 75.2% of the variance in learning outcomes is explained by Augmented Reality Media, Teacher Skills, and Motivation. These values can be categorized as substantial, suggesting that the model has strong explanatory power in predicting the endogenous constructs.

Tabel 7. VIF Inner Model

	VIF
KG -> HB	3.902
KG -> M	2.901
M -> HB	4.296
M.AR -> HB	3.726
M.AR -> M	2.901

Table 7 presents inner model VIF values for all structural paths. All values fell below the threshold of 5.0 recommended for PLS-SEM (Hair et al., 2019), ranging from 2.901 (KG→M; M.AR→M) to 4.296 (M→HB). The highest VIF for M→HB is consistent with the confirmed mediation structure but remains within acceptable bounds. These diagnostics confirm that multicollinearity does not substantially distort the structural path estimates.

Tabel 8. FIT Model

	Saturated model	**Estimated model**
SRMR	0.093	0.093
d_ULS	1.812	1.812
d_G	376.754	376.997
Chi-square	∞	∞
NFI	n/a	n/a

Table 8 reports model fit indices. The SRMR for both the saturated and estimated models was 0.093 marginally below the 0.10 threshold for PLS-SEM applications (Henseler et al., 2016). While this value indicates acceptable fit, it is acknowledged as marginal rather than strong, and should be interpreted with appropriate caution alongside the discriminant validity concerns noted above. Taken together, the measurement model provides a sufficient though not unqualified basis for proceeding to structural model interpretation.

Tabel 9. Hypothesis

	Original sample (O)	**Sample mean (M)**	**Standard deviation (STDEV)**	**T statistics (|O/STDEV|)**	**P values**
KG -> HB	0.440	0.442	0.092	4.873	0.000
KG -> M	0.483	0.482	0.088	5.495	0.000
M -> HB	0.539	0.542	0.100	5.400	0.000
M.AR -> HB	0.329	0.327	0.099	3.332	0.001
M.AR -> M	0.438	0.441	0.090	4.870	0.000

Table 9 presents the results of hypothesis testing based on bootstrapping with 5,000 subsamples. All five structural paths produced T-statistics exceeding the threshold of 1.96 and p-values at or below 0.001, indicating that all hypotheses are supported. Teacher teaching skills significantly predicted both Motivation ($\beta = 0.483$, $T = 5.495$, $p < 0.001$) and Learning Outcomes ($\beta = 0.440$, $T = 4.873$, $p < 0.001$), confirming H3 and H4 respectively. AR media was significantly associated with both Motivation ($\beta = 0.438$, $T = 4.870$, $p < 0.001$) and Learning Outcomes ($\beta = 0.329$, $T = 3.332$, $p = 0.001$), supporting H1 and H2. Motivation emerged as the strongest direct predictor of Learning Outcomes ($\beta = 0.539$, $T = 5.400$, $p < 0.001$), confirming H5. These results collectively indicate that both AR media and teacher teaching skills exert significant direct influences on motivation and learning outcomes within the PAUD context.

Tabel 10. Indirect effects

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
M.AR -> M -> HB	0.236	0.242	0.074	3.188	0.001
KG -> M -> HB	0.260	0.259	0.059	4.418	0.000

Table 10 presents the results of the indirect effects analysis. The findings indicate that the indirect effect of Augmented Reality media (M.AR) on learning outcomes (HB) through motivation (M) is positive and statistically significant (β = 0.236, t = 3.188, p = 0.001). This result suggests that motivation plays a mediating role in the relationship between the use of Augmented Reality and learning outcomes. Similarly, the indirect effect of teacher competence (KG) on learning outcomes (HB) through motivation (M) is also positive and highly significant (β = 0.260, t = 4.418, p = 0.000). This indicates that motivation significantly mediates the influence of teacher competence on learning outcomes. Overall, both indirect paths demonstrate significant mediation effects, confirming that motivation is an important intervening variable that enhances the impact of both Augmented Reality media and teacher competence on learning outcomes.

Tabel 11. Indirect effects

	Original sample (O)	Sample mean (M)	2.5%	97.5%
M.AR -> M -> HB	0.236	0.242	0.107	0.394
KG -> M -> HB	0.260	0.259	0.153	0.382

Table R^2 presents the bootstrapped R-square values for the two endogenous constructs. The model explained 76.7% of the variance in Motivation (R^2 = 0.767, T = 23.400, p < 0.001) and 75.2% of the variance in Learning Outcomes (R^2 = 0.752, T = 19.595, p < 0.001). Both values are statistically significant and substantially exceed Cohen's (1988) threshold for a large effect ($R^2 \geq 0.26$), indicating that the structural model possesses strong and statistically reliable explanatory power. The bootstrapped sample means for both constructs (M = 0.775 for Motivation; M = 0.762 for Learning Outcomes) are closely aligned with the original estimates, confirming the stability and replicability of the R-square values across subsamples.

Tabel 12. Koefisien Determinasi ($R^{2)}$

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
HB	0.752	0.762	0.038	19.595	0.000
M	0.767	0.775	0.033	23.400	0.000

Table 12 shows that the R^2 value for learning outcomes (HB) is 0.752, indicating that 75.2% of the variance in learning outcomes can be explained by the variables included in the model. Meanwhile, the R^2 value for motivation (M) is 0.767, meaning that 76.7% of the variance in motivation is explained by the model. Both values are relatively high and statistically significant (p = 0.000), suggesting that the model has strong explanatory power for both variables.

Tabel 13. f^2 Effect Size

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
KG -> HB	0.280	0.296	0.123	2.256	0.026
KG -> M	0.345	0.365	0.133	2.598	0.009
M -> HB	0.272	0.294	0.121	2.252	0.024
M.AR -> HB	0.278	0.295	0.122	2.254	0.025
M.AR -> M	0.284	0.316	0.145	1.965	0.049

Table f^2 reports Cohen's f^2 effect sizes for all five structural paths, providing a measure of each predictor's practical contribution to the explanatory power of the model beyond statistical significance alone. All five paths produced statistically significant f^2 values, ranging from 0.272 (M→HB) to 0.345 (KG→M). According to Cohen's (1988) benchmarks small ($f^2 \geq 0.02$), medium ($f^2 \geq 0.15$), large ($f^2 \geq 0.35$) the majority of paths fall within the medium-to-large range. The path KG→M yielded the largest effect size (f^2 = 0.345, p = 0.009), indicating that teacher teaching skills

exert the most substantial practical influence on motivational engagement relative to the variance unexplained by other predictors. The path KG→HB (f^2 = 0.280, p = 0.026) and M.AR→HB (f^2 = 0.278, p = 0.025) produced comparable medium-to-large effect sizes, confirming that both teacher competency and AR media make meaningful practical contributions to learning outcomes. The smallest effect was observed for M→HB (f^2 = 0.272, p = 0.024), though this remains well within the medium range and statistically significant. Collectively, these effect sizes affirm that all significant structural paths in the model are not only statistically reliable but substantively meaningful in the context of early childhood education research.

Discussion

The Influence of Augmented Reality Media on Motivation

The structural evidence confirms that Augmented Reality instructional media exerts a significant and positive effect on motivation among PAUD teachers and their students (β = 0.438, T = 4.870, p < 0.001), supporting H1. This finding is theoretically coherent within the framework of Self-Determination Theory (Ryan & Deci, 2000), which posits that motivational engagement is maximally activated when learning environments satisfy three fundamental psychological needs: autonomy, competence, and relatedness. AR technology addresses the need for competence by providing immediate, interactive, and visually confirmable feedback through digital overlays, allowing young learners to observe the consequences of their actions in real time. It simultaneously addresses the need for autonomy by enabling exploratory, child-directed interaction with digital content that responds to the learner's own inputs rather than imposing a fixed instructional sequence. In this way, AR transforms the early childhood classroom from a space of passive reception into one of active, self-directed discovery precisely the motivational conditions SDT predicts will generate the deepest and most durable intrinsic engagement.

This finding extends and corroborates the work of (Huang et al., 2019), who demonstrated that perceived enjoyment a construct closely aligned with intrinsic motivation mediated the relationship between AR usability and learning performance among elementary school students. The present investigation establishes a comparable motivational mechanism within the PAUD context, a developmental setting where motivational activation is not merely desirable but arguably prerequisite to any meaningful learning engagement. Young children in the pre-operational stage of cognitive development (Piaget, 1952) do not yet possess the metacognitive strategies that allow older learners to sustain effortful engagement in the absence of intrinsic interest. For these learners, motivation constitutes the gateway through which instruction must pass before cognitive processing of learning content can meaningfully occur. The effect size associated with this path (f^2 = 0.284, p = 0.049) confirms that AR media's contribution to motivational engagement, while the smallest among the significant f^2 values in the model, nonetheless represents a practically meaningful effect that complements the motivational influence of teacher competency.

The Influence of Teacher Teaching Skills on Motivation

Teacher teaching skills constitute the strongest single predictor of motivation in the structural model (β = 0.483, T = 5.495, p < 0.001), supporting H3, and are associated with the largest effect size among all structural paths (f^2 = 0.345, p = 0.009). This finding affirms the central theoretical claim of Self-Determination Theory (Ryan & Deci, 2000) as applied to the instructional context: the quality of the human teacher–learner relationship is the most direct and powerful source of motivational activation available in the formal educational environment. Teachers demonstrating high levels of pedagogical competency characterised by instructional clarity, adaptive responsiveness to individual learning needs, warm and emotionally attuned classroom interaction, and the capacity to scaffold children's understanding at the appropriate level of

challenge create precisely the relational and cognitive conditions under which intrinsic motivation flourishes most robustly.

In the PAUD context, the motivational significance of teacher skill is amplified by the developmental characteristics of young learners. Pre-operational children are exquisitely attuned to the emotional and relational quality of their immediate instructional environment; their capacity to sustain effortful engagement with learning content is profoundly shaped by whether the adult guiding that engagement is experienced as warm, competent, and genuinely responsive. (Hamre et al., 2013), in their development of the Classroom Assessment Scoring System (CLASS), demonstrated that teacher emotional support and instructional responsiveness were stronger predictors of preschool children's cognitive and motivational engagement than any structural feature of the classroom environment a finding the present structural evidence both replicates and extends into the technology-integrated PAUD context. The superiority of KG over M.AR in predicting motivation ($\beta = 0.483$ vs. $\beta = 0.438$; $f^2 = 0.345$ vs. $f^2 = 0.284$) further suggests that while AR technology makes a meaningful motivational contribution, human pedagogical agency retains a slight but consistent primacy as the primary architect of the motivational climate in early childhood classrooms

Stronge, (2018) argued that the defining characteristic of effective teachers is not the technical sophistication of their instructional methods but their capacity to generate the psychological conditions curiosity, persistence, and genuine intrinsic interest under which learning becomes self-sustaining rather than externally imposed. The present findings provide direct structural support for this theoretical position, establishing teacher teaching skills as the single most practically significant predictor of motivational engagement in the model and confirming that the full motivational and through motivation, achievement impact of teacher competency is expressed through this relational and psychological channel.

The Influence of Augmented Reality Media and Teacher Teaching Skills on Early Childhood Learning Outcomes

Beyond its motivational contribution, AR instructional media exerts a significant and direct positive effect on learning outcomes ($\beta = 0.329$, $T = 3.332$, $p = 0.001$; $f^2 = 0.278$, $p = 0.025$), supporting H2, and an additional significant indirect effect through Motivation ($IE = 0.438 \times 0.539 = 0.236$. The coexistence of significant direct and indirect effects confirms partial mediation of the AR–learning outcomes relationship by Motivation (H6 supported), with the total effect of AR on learning outcomes amounting to $0.329 + 0.236 = 0.565$. This dual-pathway structure establishes AR as a genuinely multifunctional instructional tool one that simultaneously reduces cognitive processing demands and amplifies the motivational engagement that sustains effortful learning.

The theoretical account of AR's direct cognitive contribution draws on (Mayer, 2009) Multimedia Learning Theory, which holds that instructional materials combining visual and auditory information in a coherent, low-redundancy format reduce extraneous cognitive load while directing available cognitive resources toward the germane processing schema construction, analogical reasoning, and conceptual integration that underlies durable knowledge acquisition. AR achieves this by overlaying contextually relevant three-dimensional digital representations onto the real-world environments already familiar to young learners, thereby reducing the representational distance between abstract instructional concepts and the child's concrete experiential reality. Rather than requiring the child to translate an abstract symbolic representation into a meaningful mental model a process placing heavy demands on the limited working memory resources of pre-operational learners AR provides a perceptually grounded

representation that is immediately accessible to the child's existing cognitive structures, freeing cognitive resources for deeper engagement with learning content itself.

These findings extend and consolidate the work of (Cai et al., 2020), who documented significant AR-driven learning gains in science education relative to conventional instruction, and (Yilmaz, 2016), who found that AR-enriched storybooks improved narrative comprehension and vocabulary retention among preschool-aged children. The present investigation advances this evidence base by establishing, through structural modelling methodology, that AR's direct cognitive contribution to learning outcomes is robust even when its substantial motivational effects are simultaneously estimated and controlled confirming that the two pathways through which AR operates are genuinely independent and additive rather than conflated. The comparable effect sizes for the direct (f^2 = 0.278) and mediated (f^2 computed through M→HB: 0.272) pathways further underscore that neither mechanism dominates: AR enriches early childhood learning through a balanced dual-channel architecture that warrants explicit recognition in both research and practice.

The Influence of Teacher Teaching Skills on Early Childhood Learning Outcomes

Teacher teaching skills demonstrate a significant and direct positive effect on learning outcomes (β = 0.440, T = 4.873, p < 0.001; f^2 = 0.280, p = 0.026), supporting H4. Additionally, a significant indirect effect through Motivation (IE = 0.483 × 0.539 = 0.260) confirms partial mediation of the KG–HB relationship by Motivation (H7 supported). The total effect of teacher teaching skills on learning outcomes (0.440 + 0.260 = 0.700) is the largest in the entire model, affirming the foundational claim of the teacher effectiveness literature that pedagogical competency constitutes one of the most potent determinants of student achievement available to educational systems (Hattie, 2012; Stronge, 2018).

This interpretation aligns with (Hamre et al., 2013) CLASS framework, which distinguishes between instructional support producing direct cognitive gains through the quality of content delivery and scaffolding and emotional support operating principally through motivational engagement and the relational climate of the classroom. The present structural findings operationalise this theoretical distinction empirically, demonstrating that both channels are active, significant, and independently meaningful in the Indonesian PAUD context. For professional development design, this implies that programmes targeting only the technical dimensions of pedagogical competency curriculum knowledge, assessment literacy, instructional sequencing will capture the direct channel while underutilising the motivational amplification channel that accounts for over one-third of teacher skill's total impact on learning outcomes.

Practical Implications for PAUD Policy and Practice

The structural findings carry three direct and actionable implications for educational policy and institutional practice within the Indonesian PAUD sector. First, the largest total effect in the model belongs to teacher teaching skills (TE = 0.700), confirming that investment in rigorous and sustained PAUD teacher professional development represents the highest-return strategy available for improving early childhood learning outcomes at scale. Professional development programmes should be designed to develop both the technical instructional competencies that produce direct learning gains and the relational and motivational facilitation skills that activate the indirect achievement channel since both contribute independently and substantially to the learning outcomes documented in this investigation.

Second, the significant dual-pathway contribution of AR media to both motivation (β = 0.438) and learning outcomes (β = 0.329), with a total effect of 0.565, provides rigorous empirical justification for institutional investment in AR-capable infrastructure within PAUD settings.

Critically, however, the present findings position AR as a complementary amplifier of skilled teaching rather than a substitute for it: the total effect of AR (0.565) falls meaningfully below that of teacher teaching skills (0.700), and the motivational primacy of teacher skill over AR (f^2 = 0.345 vs. f^2 = 0.284) confirms that technological enrichment produces its greatest returns when deployed within classroom environments already characterised by high-quality pedagogical practice. Procurement decisions and technology integration policies should reflect this complementarity.

Third, the confirmation through HTMT analysis that all discriminant validity values fall below 0.90 despite the theoretical proximity of Motivation and Learning Outcomes provides methodological reassurance that the four constructs are empirically distinct and that the structural path estimates reflect genuine construct-level relationships rather than measurement artefact. Future research should nonetheless explore whether item-level refinement can further strengthen the empirical separation between theoretically proximal constructs, and whether the motivational mediation pathways documented here replicate across diverse regional, institutional, and socioeconomic subgroups within Indonesia's heterogeneous PAUD landscape.

CONCLUSIONS

The present study examined the influence of Augmented Reality instructional media and teacher teaching skills on motivation and learning outcomes among early childhood educators in Indonesia using PLS-SEM. The findings confirm that all five direct hypotheses are supported. Teacher teaching skills significantly predicted both motivation ($\beta = 0.483$, $p < 0.001$) and learning outcomes ($\beta = 0.440$, $p < 0.001$), producing the largest total effect on learning achievement in the model (TE = 0.700). AR instructional media similarly exerted significant positive effects on motivation ($\beta = 0.438$, $p < 0.001$) and learning outcomes ($\beta = 0.329$, $p = 0.001$), with a total effect of 0.565. Motivation emerged as the strongest direct predictor of learning outcomes ($\beta = 0.539$, $p < 0.001$) and as a significant partial mediator of both the AR–learning outcomes relationship (IE = 0.236) and the teacher skills–learning outcomes relationship (IE = 0.260), with bootstrap confidence intervals excluding zero in both cases. These findings extend Self-Determination Theory into the Indonesian PAUD context, confirming that instructional quality whether human or technological operates most powerfully through the motivational engagement it activates. PAUD institutions are therefore encouraged to invest simultaneously in teacher professional development and AR infrastructure, treating motivational quality as a primary benchmark of instructional effectiveness rather than a secondary outcome.

Notwithstanding these contributions, several limitations warrant explicit acknowledgement. First, the cross-sectional research design precludes causal inference in the strict temporal sense; while the structural paths are theoretically specified and statistically robust, the directionality of the relationships for instance, whether motivational engagement precedes or follows improvements in teacher skill or AR exposure cannot be established from a single-timepoint dataset. Second, all four constructs were measured through a single self-administered questionnaire completed by PAUD teachers, introducing the risk of common method bias inherent in single-source measurement designs. Although full collinearity VIF values were examined as a procedural check, the possibility that shared method variance inflates the observed inter-construct correlations particularly between theoretically proximal constructs such as Motivation and Learning Outcomes cannot be entirely ruled out. Third, the study employed purposive sampling of certified PAUD teachers across Indonesian without stratification by province, institution type, or socioeconomic context. The substantial regional, infrastructural,

and cultural heterogeneity of the Indonesian PAUD landscape means that the structural relationships documented here may not generalise uniformly across all early childhood education settings, particularly those in rural or resource-constrained environments where AR access and teacher development opportunities differ markedly from urban counterparts.

Future research should address these limitations through three methodological directions. Longitudinal designs tracking the same PAUD teachers and their students across multiple timepoints would enable researchers to establish the temporal sequencing of the motivational mediation pathways identified here and strengthen causal interpretations. Multi-informant designs incorporating observational data on classroom motivational quality and objective assessments of child learning outcomes alongside teacher self-report would substantially reduce common method variance and provide a more ecologically valid account of the structural relationships. Experimental or quasi-experimental designs systematically varying AR exposure and teacher development conditions would further enable stronger causal conclusions about the independent and combined contributions of these instructional inputs to early childhood learning outcomes across Indonesia's diverse PAUD landscape.

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