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ORIGINAL PAPER

Motivation as a Driver of Engagement in Augmented-Reality Learning in Primary Schools

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Abstract

There is growing evidence that immersive learning can enhance motivation and engagement. However, research that explores how motivational states are transformed into engagement, especially within the context of Augmented Reality (AR) is rather underdeveloped. The current study aims at predicting and explaining student engagement in terms of the four motivational dimensions of the ARCS, namely attention, relevance, confidence and satisfaction. The study used an explanatory mixed methods design comprising an online survey followed by semi-structured interviews. 106 pupils from four Scottish primary schools participated in a series of AR-supported learning activities embedded in the classroom curriculum. Partial Least-Squares analysis explained approximately 55% of the variance in pupil engagement in terms of their motivational levels of attention, relevance, and satisfaction, demonstrating a moderate-to-strong predictive capability. The followed-up qualitative analysis of the structured interviews provided a more in-depth analysis of how ARCS motivational dimensions influence pupils' engagement. Study findings can help researchers to better understand the dynamics linking motivation and engagement. It can also help practitioners in designing more engaging and impactful AR-supported learning activities, targeting young learners.

Keywords Augmented reality · Primary education · Motivation · ARCS model · Engagement

Introduction

Augmented Reality (AR) is the technology that enhances the physical environment by superimposing computer-generated content onto the real world (Furht, 2006). Real world objects are linked to virtual elements through various triggers (e.g., geographic locations, QR codes, etc.) so the user can interact with these elements while navigating through the physical environment. AR allows for the visualization of abstract and invisible concepts, offers interactive learning opportunities, increases student interest and satisfaction (Akçayır & Akçayır, 2017) and improves learning outcomes by supporting long-term knowledge retention (Chang et al., 2022). Research provided evidence that AR can enhance learning experiences by making them more engaging, interactive, and personalized (Garzón, et al., 2019).

The capacity of AR to enhance student motivation and engagement is one of its most reported benefits in educational settings (Garzón, et al., 2020; Akçayır & Akçayır, 2017; Chang et al., 2022). Motivation plays a critical role in shaping students' meaningful engagement in the learning process (Boekaerts, 2016; Reeve, 2012). However, while motivation is often regarded as a prerequisite for engagement, the transformation of motivation to engagement depends on other mediating factors as well. For example, even if students feel motivated, they may not engage if they do not feel competent enough or appropriately supported in the learning environment (Skinner et al., 2009). Another example of low engagement despite high motivation arises when the instructional design lacks sufficient autonomy support to foster student agency (Reeve & Tseng, 2011).

Although motivation and engagement have been widely studied (Keller, 2008), most research has examined them together, often without distinguishing the mechanisms that link the two. Many studies have explored the impact of immersive learning environments on motivation and engagement (e.g., Huang, et al., 2021; Ji et al., 2025; Lin &

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Yu, 2023; Sdravopoulou et al., 2021), however to the best of our knowledge, with few exceptions (e.g., Kim et al., 2015), limited research explicitly examines how motivation is transformed into actual student engagement, particularly in the context of augmented reality. Our study addresses this gap and examines how different motivational dimensions influence students' engagement in AR-supported learning environments. The paper is organized as follows: Section "Literature Review" provides the background and literature review; Section "Conceptual Framework and Hypotheses" the conceptual framework and hypotheses; Section "Methodology" presents the methodology; Section "Data Analysis and Results" presents the data analysis and results, and Section "Discussion and Conclusions" discusses the findings that emerged from the analysis and the conclusions addressing the implications of the findings and possible directions for future research.

Literature Review

Research has demonstrated that AR holds significant potential for education (Garzón, et al., 2020; Perifanou et al., 2023). Studies have found that AR can support the visualization of abstract concepts and improve knowledge retention (Arici et al., 2021), promote collaboration among learners (Chang & Hwang, 2018), and increase learner enjoyment (Belda-Medina et al., 2022). Moreover, AR by immersing students in authentic environments, can support situated learning, promote exploratory learning and facilitate knowledge construction in real world contexts (Bacca et al., 2014). Such affordances contribute to learners' higher levels of motivation and deeper engagement in the learning process (Garzón, et al., 2020; Perifanou et al., 2023).

Even though motivation and engagement are among the most reported benefits AR in educational settings (Akçayır & Akçayır, 2017; Chang et al., 2022), the precise mechanisms that link the two, especially in technology-mediated and immersive learning environments remain relatively under-explored. Skinner et al. (2009) have shown that even highly motivated students may fail to engage due to their low self-efficacy levels or lack of contextual support and scaffolding. Reeve and Tseng (2011) provided evidence that the lack of autonomy support can have a negative impact on the level of student engagement in the learning activities. Moreover, research has shown that instructional design plays a crucial role in facilitating or hindering student engagement (West, 2018). Learning tasks that lack coherence and clarity can lead to student disengagement (Evans et al., 2024). Multimedia instruction, if poorly designed, can potentially impose significant cognitive load on learners, and this can have a negative impact on engagement (Mayer, 2024). The literature review by Buchner, et al. (2022) highlighted that this can be the case for augmented reality-enriched learning and training too. For example, augmented reality learning experiences that are not developed based on the contiguity principle of multimedia learning can result in significant decrease in motivation and engagement (Lai et al., 2019). Motivated students may also disengage when instructional content is not aligned with their personal interests or goals (Jones, 2009; Simons et al., 2004). These findings suggest that motivation, though required, is not always sufficient to guarantee learners' engagement; learners must also consider the learning instruction to have clarity, provide autonomy, support competence and be aligned with their personal needs and goals.

Nevertheless, studies in educational psychology and instructional design have attempted to establish a link between motivation and engagement; motivating students to engage in learning is an area that has been extensively studied in the context of educational psychology and instructional design. Brett (2009) proposed the MUSIC model to academic motivation comprising five components that an instructor should consider when designing instruction, e.g., empowerment, usefulness, success, interest, and caring. van Merriënboer (1997) (2005, in his four-component instructional design (4C/ID) model proposed motivational scaffolds through authentic tasks that can increase engagement. Merrill's first principles of instruction (Merrill, 2002) support motivation and increase engagement through meaningful context and problem-solving learning activities. Reeve (2013) introduced the concept of agentic engagement to create autonomy and therefore motivationally supportive learning environments for students. Keller (2008) proposed the ARCS model of instructional design comprising four key elements: attention, relevance, confidence, and satisfaction. The ARCS model was designed to enhance learner motivation by creating learning experiences that can capture attention, establish relevance, build confidence, ensure satisfaction, and therefore support engagement and improve learning outcomes. However, most studies have examined motivation and engagement together, without clearly distinguishing the dynamics connecting the two. To the best of our knowledge, limited research exists to explore how motivation is transformed to engagement or how certain instructional design characteristics can facilitate this transformation. For example, Nikou and Economides (2018) predicted and explained students' engagement in mobile-assisted inquiry-based science learning in terms of the Self-Determination Theory of motivation (Deci & Ryan, 2002). They found that perceived autonomy is the strongest predictor of engagement, followed by perceived relatedness. Similarly, while there is growing evidence that immersive learning can enhance motivation and engagement, limited research has explored how motivational

states are transformed into engagement within these contexts. Bacca et al. (2019) proposed a framework for designing motivational augmented reality applications in vocational education and training built upon motivational design, universal design for learning and co-creation. Chen et al. (2025) experimented with a self-regulated learning model integrating augmented reality with peer assessment to facilitate young students' engagement with writing. Zhang and Miao (2025) provided evidence that motivation significantly predicts engagement; EFL students who are more motivated (e.g., confident, interested, goal-oriented, and persistent) are more likely to actively engage in learning tasks using AI and AR/VR tools, therefore motivation significantly predicts engagement.

Further exploration of already established motivational instructional components that can enhance engagement would be helpful to better understand the underlined mechanisms and design more engaging learning experiences. Our study uses the well-established ARCS instructional model of motivation to explain and predict student engagement in AR-supported learning activities. Moreover, while students' engagement is usually considered as a multi-dimensional construct comprising of behavioral, cognitive and emotional dimensions (Fredricks et al., 2004), research reports that these dimensions often interact dynamically and co-occur in educational settings (Fredricks & McColskey, 2012). Our study, in order to capture this interplay of the motivational dimensions holistically rather than examining them in isolation, evaluates engagement as a single construct. Explaining and predicting student engagement (including its behavioral, cognitive and emotional components) in terms of the four motivational dimensions of the ARCS, will improve our understanding on how motivational drivers influence primary school pupils' engagement in educational AR which is crucial for maximizing the AR potential in educational settings.

Conceptual Framework and Hypotheses

This study uses the ARCS model of motivation (Keller, 1987) and Fredricks et al. (2004) method of studying student engagement as its theoretical background.

The ARCS model of motivation provides a comprehensive framework for understanding how to support and sustain learners' motivation through four key elements: attention, relevance, confidence, and satisfaction. Attention is the first component of ARCS, and it refers to capturing and maintaining learners' interest and attention. Relevance, the second component, involves the perceived value and applicability of learning to students' personal goals and experiences or real-world applications. Confidence, the third component, refers to a learner's belief in their ability to succeed in the learning tasks. Satisfaction is the furth component and it is defined as the pleasure learners feel when they perform or complete a learning activity.

The ARCS model has been used in a variety of educational settings (Fang et al., 2023; Ma & Lee, 2021; Mirzaei et al., 2022) and while research outcomes differ, most studies reported an increased level of learners' motivation associated to its implementation (Li et al., 2018). Research provides evidence that blending digital elements with real-world environments is an efficient way of igniting students' interest and attention (Perifanou et al., 2023). Due to its interactivity and immersive capacity, AR can support and elevate learners' motivation (Prasetya et al., 2024). In terms of the ARCS elements, AR technology has the capacity to sustain attention and interest in learning by offering real-time 3D visualizations (Hao & Lee, 2019). AR can support relevance since connections with the real world are central to how this technology works, as AR overlays digital elements onto real objects (Laurens-Arredondo, 2022). Moreover, AR can offer appropriate challenges and scaffolding reinforcing students' belief in their ability to succeed and enhancing thus their confidence levels (Akçayır et al., 2017). AR makes learning more enjoyable (Nikou & Economides, 2018) and satisfaction is reported as one of the main factors that affects student engagement in AR learning environment (Nikou & Economides, 2018).

The ARCS motivation model was developed to help educators create instructional strategies that better address students' motivational needs, ultimately improving their engagement and performance (Fang et al., 2023). ARCS is theorized to stimulate and sustain motivation (Keller, 2008) and motivation is usually considered as a prerequisite for engagement (Boekaerts, 2016). Studies exist to evaluate motivation or learning outcomes, however, to the best of our knowledge, very few studies exist on how ARCS components specifically lead to measurable engagement, especially in AR learning environments (Huang et al., 2021).

Measurement of student engagement is a rather challenging and various methods have been proposed (Fredricks, & McColskey, 2012). The conceptualization of engagement through the lens of the behavioral, emotional and cognitive dimensions (Fredricks et al., 2004, Fredricks et al., 2005) remains one of the most widely accepted frameworks (Li, 2022). Based on Fredricks et al. (2012), behavioral engagement is associated with active participation and effort in the learning activities. Cognitive engagement refers to the extent to which learners are mentally invested in learning. Emotional engagement relates to the student's feelings of interest, enjoyment, frustration, boredom, and anxiety in the classroom. Empirical studies support the

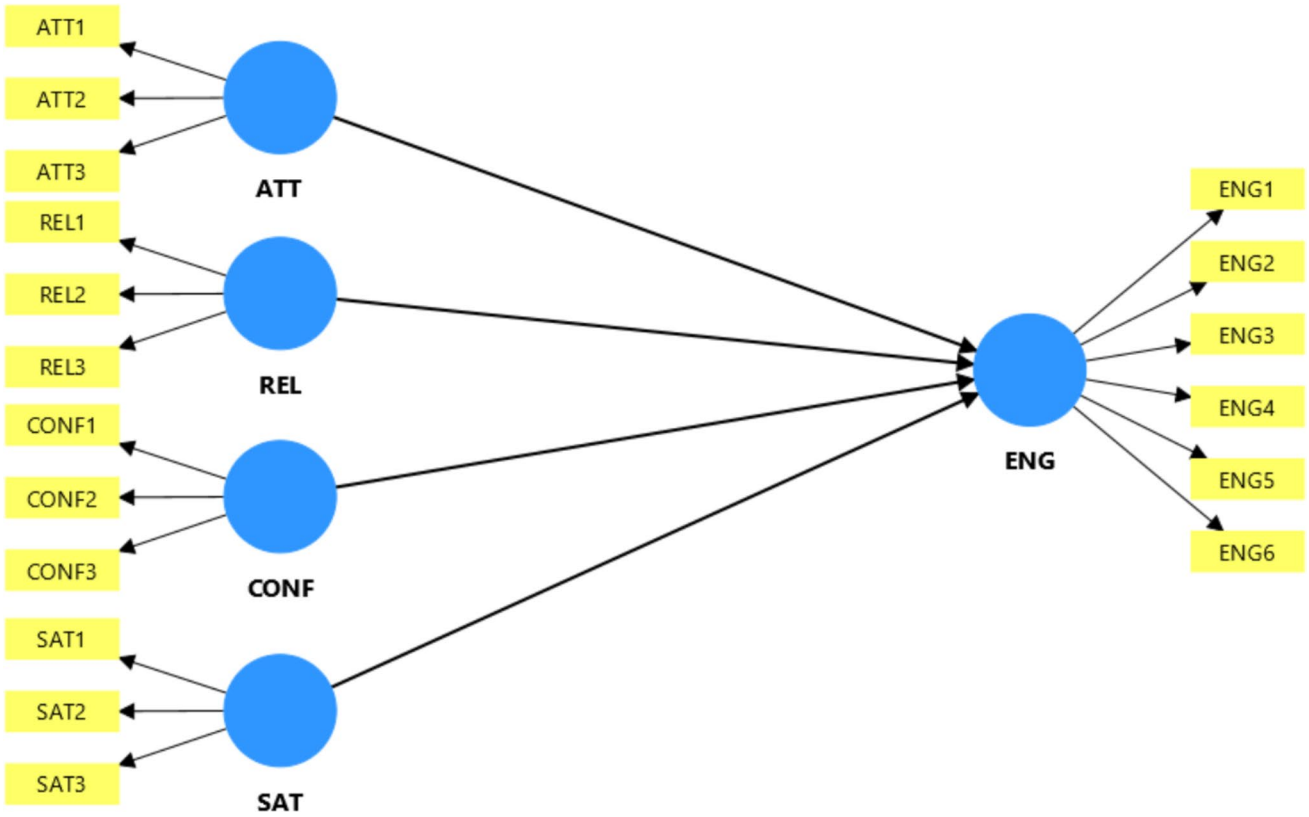

Fig. 1 The proposed model

view that these dimensions interact dynamically and often co-occur in educational settings (Fredricks & McColskey, 2012). Therefore, conceptualizing engagement as a single latent variable allows for a more holistic understanding of how students engage in learning tasks and environments. Combining individual indicators from each dimension into one construct not only reflects this interdependence but also provides analytical simplicity when examining relationships with other constructs, such as motivation or technology use. Moreover, the overall level of engagement is more critical than the distinction between the different dimensions.

Our study will follow this integrated approach and connect the dimensions of the ARCS model to the concept of engagement aiming to exploring how the motivational dimensions of attention, relevance, confidence and satisfaction affect pupils' engagement in AR-supported learning activities. Considering that motivation is widely recognized as a prerequisite for engagement (Fredricks, et al., 2004; Reeve, 2012), we hypothesize the following for the ARCS dimensions of motivation.

H1. Attention (ATT) has a positive influence on pupils' engagement (ENG) in AR enhanced learning activities.
H2. Relevance (REL) has a positive effect on pupils' engagement (ENG) in AR enhanced learning activities.
H3. Confidence (CONF) has a positive effect on pupils' engagement (ENG) in AR enhanced learning activities.
H4. Satisfaction (SAT) has a positive effect on pupils' engagement (ENG) in AR enhanced learning activities.

Figure 1 depicts the proposed theoretical model.

Methodology

Participants and Procedure

The study was conducted over a two-week period within the context of the primary school computing curriculum, specifically targeting the development of digital solutions in response to a defined challenge. The participant cohort comprised 106 pupils (58 females, 55%; 48 males, 45%) aged 10 −11 years, drawn from Primary 5 and 6 classes across four primary schools in Scotland. Ethical approval for the study was obtained from the Strathclyde Institute of Education Ethics Committee.

Two digital tools—CoSpaces Edu and MERGE Cubes -were employed to support the learning activities. CoSpaces Edu is an educational platform that enables users to create interactive digital artefacts and immersive AR/VR

experiences without requiring programming skills. MERGE Cubes facilitate interaction with three-dimensional digital content through augmented reality. Both technologies have been successfully integrated into prior educational research [48, 49]. The learning activities were guided by Keller's ARCS model, capturing Attention, ensuring Relevance, building Confidence, and fostering Satisfaction, aiming to enhance pupil motivation and sustained engagement.

During the first week, pupils were introduced to the core functionalities of CoSpaces Edu and MERGE Cubes through teacher-led demonstrations, after which they engaged in exploratory practice in pairs. Provocative prompts like "What would it look like if a famous Olympian came alive on your desk?" served to capture attention. Relevance was established by linking AR to real-world applications, games and storytelling. Moreover, pupils explored pre-built AR scenes in pairs and had been assigned relatively easy tasks allowing each pair to modify a sample scene, fostering creativity and providing an early sense of achievement.

During the second week, pupils began developing their own AR projects. Interest was re-sparked by showcasing last week's creations and introducing potential small-scale projects. The paired pupils selected their presentation topics aligned with ongoing class projects, i.e., notable Olympians, historical explorers, or autobiographical content, increasing relevance and personal investment. Pupils gathered relevant textual and visual resources, which were then incorporated into their digital augmentations. These resources included interactive features, such as animated figures performing thematic actions (e.g., athletes running or explorers navigating around the cube) or voice and sounds recordings. Pupils' confidence was supported through researching, storyboarding, building, and reviewing the presentations. Peer feedback loops further reinforced learning. The learning activities ended with the students showcasing their work followed by a short reflection where they talked about what they enjoyed and found challenging.

Following the completion of the instructional activities, data was collected in two stages using an explanatory mixed methods design (Creswell & Clark, 2017), comprising an online survey followed by semi-structured interviews. First stage was about gathering quantitative data on student motivation and engagement through a Qualtrics online survey distributed to all pupils. Participation in the survey was entirely voluntary, and responses were anonymised to ensure confidentiality. The use of quantitative methods allows for the systematic measurement of key motivational constructs, as defined by the ARCS model (Attention, Relevance, Confidence, Satisfaction), and the multi-dimensional aspects of learner engagement in AR-based environments. Since motivation and engagement are rather complex, context-sensitive constructs that are not always fully captured through numerical measures alone, inclusion of qualitative methods in the second phase enables a deeper exploration of students' experiences and perceptions. Therefore, second stage was about collecting qualitative data about student motivation and engagement through semi-structured interviews. Interviews were conducted with five pupils from each of the four participating schools to ensure a range of perspectives and experiences were captured. Pupils were selected by their teachers to represent a mix of ages, abilities, and engagement levels, and were invited to take part only if they had chosen to participate willingly. All responses were anonymised to ensure confidentiality.

Instruments

The questionnaire used aimed to capture primary pupils' motivation and engagement during the AR-supported learning activities. Motivation levels have been gauged using the ARCS model of motivation (Keller, 1987, 2010). The model and questionnaire items used have been validated in previous studies (Li & Keller, 2018). Indicatively, adopted items were as follows. For attention, "The AR activities helped me to stay focused" and "The AR activities kept my attention throughout the lesson". For relevance, "The things I am learning in this course will be useful to me". For confidence, "I felt confident to successfully complete the AR activities" and "I felt confident that I can do well in this class". For satisfaction "I felt satisfied by doing the AR activities". For the pupils' engagement, we adopted items from the engagement questionnaires developed by Wang et al. (2016) and Fredricks et al. (2004) These validated instruments evaluate students' behavioral, emotional and cognitive engagement in learning activities. Examples items for behavioral engagement were "I pay attention in class during the AR activities", for emotional engagement "I enjoy learning using AR" and for cognitive engagement "I try different ways to build an AR project". All question items were measured on a 5-Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). The adopted questionnaire items were initially piloted with a small group of students and subsequently refined for clarity and precision.

Data Analysis and Results

Quantitative Data

In order to explain and predict pupils' engagement in Augmented Reality supported learning activities in terms of their motivational levels of attention, relevance, confidence and satisfaction, we employed Partial Least-Squares as a main predictive modelling method (Chin, 1998) and used

SmartPLS4 (Ringle et al., 2024). Our sample size is more than the suggested threshold of 30, which is equivalent to 10 times the maximum number of independent variables influencing a dependent variable (Chin, 1998).

Instrument Validation

For the quality of the proposed model, we have considered its internal consistency, convergent and discriminant validity. All requirements for convergent validity are satisfied. Each factor loading on each relative construct exceeds 0.70, each construct's composite reliability exceeds 0.70, and every average variance extracted (AVE) value exceeds the variance resulting from measurement error for that construct with values from 0.628 to 0.799 (AVE > 0.50) and 1 for the single-item construct (Table 1). Also, the square root of the average variance extracted (AVE) of a construct is higher than any correlation with another construct, which supports discriminant validity (Table 2). Thus, both convergent and discriminant validity for the proposed research model are verified (Hair et al., 2014).

Table 2 Discriminant validity for the measurement model (values in bold: the square root of the average variance extracted for each construct)

	ATT	CONF	ENG	REL	SAT
ATT	**0.828**				
CONF	0.394	**0.894**			
ENG	0.647	0.399	**0.793**		
REL	0.540	0.435	0.552	**0.806**	
SAT	0.631	0.424	0.638	0.435	**0.792**

ATT Attention, *CONF* Confidence, *ENG* Engagement, *REL* Relevance, *ENG* Engagement

Test of the Structured Model and Hypotheses

The path coefficients' values, their significance, and the variance (measured by R2) measured by the antecedent constructs, all support the suggested structural model and its hypotheses. The results from the PLS analysis support three out of our four hypotheses (hypotheses H1, H2 and H4 are confirmed while H3 is rejected). A bootstrapping procedure has been applied to measure the t-values and the variance measured (R2) by the antecedent constructs. Table 3 presents a summary of the structural model along with the

Table 1 Descriptive statistics and results for convergent validity for the measurement model (acceptable threshold values in brackets)

Construct Items	Mean (SD)	Factor Loading (> 0.70)	Cronbach's a (> 0.70)	Composite Reliability (> 0.70)	Average Variance Extracted (> 0.50)
Attention	4.377		0.772	0.777	0.686
ATT1	(0.547)	0.833			
ATT2		0.857			
ATT3		0.794			
Relevance	4.333		0.732	0.751	0.649
REL1	(0.817)	0.804			
REL 2		0.848			
REL 3		0.763			
Confidence	4.836		0.874	0.874	0.799
CONF1	(0.327)	0.885			
CONF 2		0.914			
CONF 3		0.883			
Satisfaction	4.701		0.701	0.704	0.628
SAT1	(0.529)	0.821			
SAT2		0.722			
SAT3		0.829			
Engagement	4.320		0.882	0.889	0.628
ENG1	(0.787)	0.710			
ENG2		0.779			
ENG3		0.823			
ENG4		0.818			
ENG5		0.817			
ENG6		0.802			

Table 3 Hypothesis testing results

Hypothesis	Path	Path coefficient	Results
H1	Attention (ATT) → Engagement	0.297**	Supported
H2	Relevance (REL) → Engagement	0.229**	Supported
H3	Confidence (CONF) → Engagement	0.041	Not Supported
H4	Satisfaction (SAT) → Engagement	0.333**	Supported

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

Fig. 2 Pupils working with AR

confirmed results of the hypothesis testing and Fig. 2 shows the path coefficient for each confirmed path.

The standardized path coefficients for the three supported hypotheses H1, H2 and H4 have values 0.297, 0.229 and 0.333 respectively (values that are considered to be medium to large [38]. The model explains 54.7% of the variation in pupils' engagement with AR enhanced lessons (R2 = 0.547).

Three out of four motivational constructs of the ARCS model (Attention, Relevance and Satisfaction) significantly predict engagement while Confidence does not seem to have a significant impact. Attention is a significant predictor of engagement (0.297), therefore capturing and maintaining primary pupils' attention is crucial for engagement. Relevance is also a significant predictor of engagement (0.229). If the material feels connected to pupils' interests, they are more engaged. Also, satisfaction is a significant predictor of engagement (0.333); when pupils are satisfied with their learning and feel that their efforts are worthwhile, and enjoyable, they are more likely to engage in learning. Confidence is not a significant predictor (0.041). It seems that younger children may engage in a learning activity even without high confidence, as they are still exploring and adapting to learning environments (Fig. 3).

An R^2 value of 0.547 indicates that the ARCS model explains approximately 54.7% of the variance in pupil engagement, demonstrating a moderate-to-strong predictive capability.

Qualitative Data

While the PLS-SEM model provides some meaningful statistical associations, it does not fully capture the richness of pupils' lived experiences with AR. Therefore, in the follow

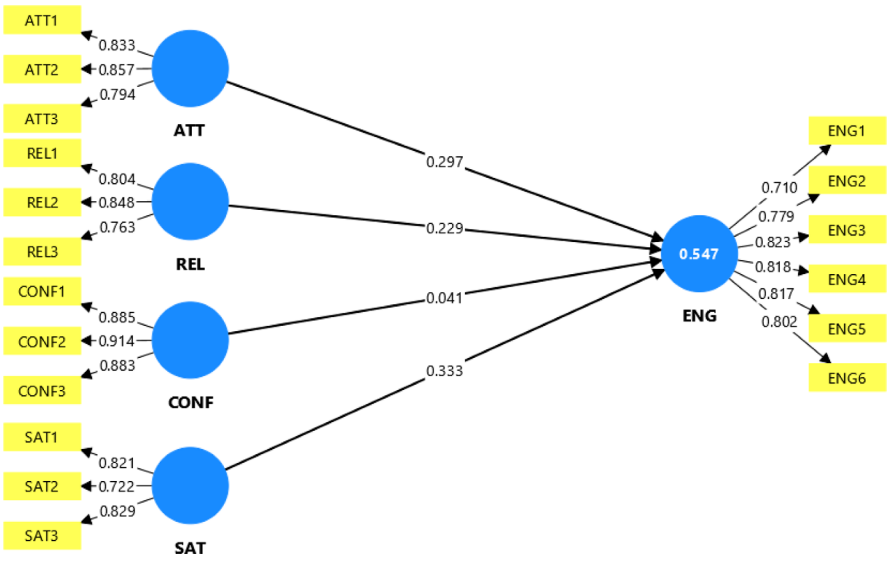

Fig. 3 PLS research model results

Table 4 Themes and subthemes for ARCS

ARCS	Subtheme	Characteristic Quote
Attention	Novelty of AR	"It's really cool, because you put a lot of effort into doing it then you see it come to life"
	Excitement/Fun	"It's fun. It's cooler than words", "I also feel excited to do it again"
Relevance	Connection to Real Life	"I feel like it relates to our everyday life because our everyday life is coming here to school and learning"
	Link to Curriculum	" Links to the things that I like, because I like drawing and doing art and and you can do that on the merge cube"
	Personalisation	"I liked creating the all about me. Like so. Like creating like the picture of the person and writing about it on the merge cube"
Confidence	Accomplishment	"I felt proud and a wee bit more confident to do it again"
Satisfaction	Enjoyment of Outcome	"It was fun. And I would want to do it more and more again"
	Ownership of Learning	"A better way of explaining your imagination, instead of saying"

up stage, we analyzed the qualitative data collected from pupils through the semi-structured interviews. We have followed the six-phase model proposed by Braun and Clarke (2006), i.e. (i) familiarization with the data, (ii) generation of initial codes, (iii) theme identification, (iv) review and refinement, (v) naming and defining of themes, and (vi) final narrative development. In the familiarization phase, all interviews and classroom notes were transcribed and reviewed multiple times. We have used manual thematic to ensure deeper, reflexive engagement and interpretive judgment with the data. During familiarization, all interviews were transcribed and reread multiple times so researchers could better understand pupils' experiences, i.e. not only *what is happening* but *why it is happening*.

The data have been analyzed using a deductive approach with a pre-determined coding scheme based on the ARCS motivation model (Attention, Relevance, Confidence, Satisfaction) and established engagement dimensions (behavioural, cognitive, emotional), operationalized from validated scales and our priori hypotheses. We used a theory-driven (deductive) scheme to ensure construct validity and comparability with the quantitative instruments: the motivational (ARCS) and engagement scales. Using a theory-driven scheme aligned with established constructs (ARCS and engagement dimensions) ensures construct validity, comparability with prior work, and direct alignment with our survey measures and hypotheses (Fereday et al., 2006). Anchoring codes to validated constructs helped to draw a clear line from constructs to codes and themes and triangulate with linked survey items (Anfara et al., 2002).

During the initial code generation, observable indicators translated into code definitions and mapped to ARCS and engagement. For the theme identification, review and refinement stages we identified, reviewed, and refined themes by clustering related codes into.

clustered related codes into the themes mapped to the themes aligned with the ARCS and engagement constructs.

Table 5 Themes and subthemes for engagement

Engagement	Subtheme	Characteristic Quote
Behavioral	Active Participation	"…when we got to try out the games and got to like explore …", "I would say it definitely made me like more engaged with all the learning like I was more excited to do it than I used to be like"
	Persistence	"At first, I could not get my head around how to work it and once it was finished, it all came out into one big thing"
Emotional	Enjoyment/Fun	"And it was like, so funny", "…once you learn you will have so much fun doing it"
	Pride/Satisfaction	"I felt proud and a wee bit more confident to do it again"
Cognitive	Focus and Attention	" So you're actually more focused and interested in it" "You needed to stay focused, because if you did something wrong, it wouldn't turn out right"
	Creativity and Imagination	"You can just let your imagination run free"

This kind of deductive analysis offers a richer approach to better understand pupils' AR experience in relation to motivation and engagement subscales (Bingham & Witkowsky, 2022).

The analysis of pupils' feedback revealed themes that were aligned with the surveyed constructs and encompassed pupils' perspectives on ARCS and Engagement. These themes are Attention, Relevance, Confidence, Satisfaction and Behavioral, Emotional and Cognitive Engagement, each reflecting a distinct dimension of how the intervention was experienced.

Tables 3 and 4 below outline the codes and analytical focus underpinning each theme, offering transparency around the interpretive process that shaped the thematic structure.

The Attention theme explores how pupils' attention was captured through the novelty of AR and the excitement and fun it generated. Codes contributing to this theme included novelty, fun, and excitement. Pupils frequently described the AR activities as "fun," "magical," and "cool," showing strong novelty and appeal. These responses provide insight into how the unique and engaging qualities of AR can stimulate curiosity and sustain learners' focus on AR-supported learning.

The Relevance theme explores how pupils connected AR experiences to real life, the school curriculum, and personalised learning pathways. Codes contributing to this theme included real-world connection, curriculum link, and personalisation. Quotes like "And you think it links to your everyday life because your everyday life is being in school" and "It's really cool to think that ipads and phones we use in our everyday life to use for phone calls and things with them for years" show how AR connects to pupils' real-world experiences and personal interests. These responses provide insight into how aligning AR activities with pupils' lived experiences and learning objectives can enhance the perceived value and meaningfulness of AR-supported learning.

The Confidence theme explores how pupils develop a sense of accomplishment through AR activities. Codes contributing to this theme included achievement, success, and capability. Confidence was often expressed through increased self-efficacy, e.g., "I felt proud and wee bit more confident to do it again", highlighting how AR can foster mastery and reduce anxiety compared to traditional methods. These responses provide insight into how AR-supported learning can foster self-efficacy and build pupils' confidence in their ability to engage with and master new tasks.

The Satisfaction theme explores how pupils valued the enjoyment of outcomes and the sense of ownership over their learning. Codes contributing to this theme included enjoyment, pride, and ownership. For example, a pupil said, "It felt less like an actual subject that felt more like something I'd choose to do in my free time" and another "It was fun. And I would want to do it more and more again". These responses provide insight into how AR-supported learning can reinforce positive experiences and sustain long-term motivation through rewarding outcomes.

The analysis of pupil interviews revealed also strong engagement across the behavioral, emotional, and cognitive dimensions when using AR in the classroom.

The Behavioural Engagement theme explores how pupils demonstrated active participation and persistence during AR activities. Codes contributing to this theme included participation, effort, and perseverance. Pupils showed high levels of active participation, describing how they enjoyed "exploring" and "building stuff and drawing" and demonstrated persistence, overcoming technical challenges through repeated effort.

These responses provide insight into how AR-supported learning can encourage sustained involvement and commitment to tasks, reflecting pupils' engagement at the behavioural level.

The Emotional Engagement theme explores how pupils' feelings of enjoyment, fun, pride, and satisfaction shaped their experiences with AR activities. Codes contributing to this theme included enjoyment, fun, pride, and satisfaction.

Pupils' responses highlighted deep enjoyment, with one pupil noting that it "felt more like something I'd choose to do in my free time" and a strong sense of pride and satisfaction, as another stated they felt "proud and a wee bit more confident to do it again" or "…it made me feel very confident with our topic". These responses provide insight into how positive emotions fostered through AR-supported learning can deepen pupils' connection to the activity and enhance overall engagement.

The Cognitive Engagement theme explores how pupils demonstrated focus, attention, creativity, and imagination while interacting with AR activities. Codes contributing to this theme included concentration, creative thinking, and imaginative responses. Pupils were well focused, especially compared to traditional lessons. One pupil commented, "So you're actually more focused and interested in it" while many pupils emphasized the role of creativity, by reporting that AR "You can just let your imagination run free". These insights highlight how AR-supported learning can stimulate higher-order thinking and sustain mental investment in learning tasks (Table 5).

The mixed-methods described above provided a holistic understanding of the AR classroom experience: the PLS-SEM model quantifies the predictive strength of ARCS on engagement, while qualitative insights unpack the mechanisms, contexts, and emotions driving those patterns.

Discussion and Conclusions

The aim of the current study is to improve our understanding of how motivational drivers influence primary school pupils' engagement in AR-supported learning environments. The study used an explanatory mixed methods design (Creswell & Clark, 2017), comprising an online survey followed by semi-structured interviews. The utilized explanatory mixed methods design not only provides a better understanding combining measurable outcomes with subjective experiences, but it strengthens the validity of the study by having the qualitative data elaborating the patterns identified in the quantitative stage (Twining et al., 2017).

The structural model explained approximately 55% of the variance in pupil engagement through motivational dimensions of attention, relevance, and satisfaction, indicating a moderate to strong level of predictive power. Confidence was not found to be a significant predictor of engagement. A possible explanation is that primary school pupils, being in a developmental stage, tend to engage more strongly when driven by other factors such as attention or relevance and satisfaction, rather than by their own confidence levels. At this age, pupils are generally curious and willing to take risks, thereby reducing the role of confidence in driving engagement.

To have a more in-depth understanding of how ARCS dimensions influence pupils' engagement, the quantitative analysis complemented with a qualitative thematic analysis of pupils' interviews. The qualitative analysis revealed convergent evidence across interviews and strengthened the credibility of the identified themes. The use of deductive thematic analysis connected a theory-based approach to our themes, tracing themes to specific data sources, and showing triangulation aligning each theme with evidence from multiple data sources i.e., interviews and survey items (Anfara et al., 2002). The thematic analysis identified the following themes with each one mapping to a specific ARCS motivational dimension. Attention is driven by the novelty of AR, as well as the excitement and fun it generates. Relevance is attributed to connections to real life, curriculum links and personalized learning. Confidence arises from a sense of pupils' accomplishment during AR activities. Satisfaction is a consequence of the enjoyment of the outcome and the ownership of learning. Findings agree with previous motivation research. Based on Li et al. (2023), fulfillment of the first three motivational components (attention, relevance and confidence) in mobile AR increases learning and engagement in writing activities while the last stage of satisfaction determines continuous intention to use. Interest and satisfaction have been found to lead to engagement in maker activities (Nikou, 2024) and mobile-based Augmented Reality (Nikou, 2026). Interest, confidence satisfaction and goal orientation have been identified by other studies as well as motivational factors contributing to engagement (Zhang & Miao, 2025) in immersive environments.

Moreover, the thematic analysis identified the following subthemes related to the engagement embedded dimensions. Behavioral engagement is attributed to active participation and persistence. Emotional engagement is driven by enjoyment and pride. Cognitive engagement results from focus and creativity. Another study by Nikou and Economides (2018) identified autonomy, competence and relatedness as the main determinants of engagement. Active participation is related to the need for competence. Enjoyment and pride are often driven by the sense of connecting and collaborating with others. Focus and creativity often are supported by learners' autonomy where learners have the freedom to explore and make choices.

Our study is important because, to the best of our knowledge, it is one of the first systematic efforts that attempt to explain and predict pupils' engagement with educational AR in terms of the components of the ARCS model of instructional design. While many studies have explored the impact of immersive learning environments on motivation and engagement (e.g., Huang, et al., 2021; Ji et al., 2025; Lin & Yu, 2023), limited research explicitly

examines how motivation is transformed into actual student engagement, particularly in the context of augmented reality (e.g., Li et al. 223). Our study is grounded on the established ARCS model and systematically investigated how motivational factors contribute to pupils' engagement in AR. Understanding how motivation is transformed to engagement through appropriate design can help shape future educational policies and practices. Exploring how each dimension of the ARCS model contributes to engagement can help practitioners decide which one is more impactful to emphasize in their design. For example, since attention, relevance and satisfaction have found to be strong predictors, designers can focus more on creating inspiring, authentic and meaningful and satisfying learning AR experiences.

Moreover, since our study focuses on how primary pupils engage with AR, it can help educators and developers to better tailor educational AR applications for this age group. Early engagement with innovative learning tools such as AR could influence children's long-term academic success and attitude toward learning, making AR a potentially transformative tool in modern education (Nikou, Perifanou, & Economides, 2025). The study can inform the design of AR tools that are developmentally appropriate, engaging, and effective for young learners, ensuring that these technologies are both fun and pedagogically sound.

One of the main limitations of the study is its relatively short duration. Assessing a more lasting impact would be needed to avoid the novelty effect that could have temporarily resulted in increased engagement. More longitudinal studies with other age groups and with a deeper integration of AR in the curriculum would be helpful. In summary, the study improves our understanding of how motivational drivers influence primary school pupils' engagement in AR-supported learning environments.

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Data Availability Data can be available upon reasonable request.

Declarations

Compliance with Ethical Standards The study was granted approval from the Ethics Committee of the Strathclyde Institute of Education, University of Strathclyde.

Competing interests The authors have no competing interests to declare that are relevant to the content of this article.

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