

Chapter

Mixed Reality as Financially Enabled Learning Infrastructure: A Case Study of Academic Self-Efficacy and Self-Regulated Learning in Engineering Education

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Abstract

Mixed reality (MR) environments represent a significant capital investment in higher education infrastructure and may shape students' self-regulated learning (SRL), academic self-efficacy, and professional development. Aligning with broader debates on education finance and human capital cultivation, this mixed-methods case study examines how a HoloLens 2-supported MR learning environment influenced undergraduate civil engineering students' confidence, performance, and regulatory processes during a Revit-based design task. The case was bounded within a specific institutional context and involved eight third-year students and three civil engineering lecturers at the Chang'an–Dublin International College of Transportation. Grounded in social cognitive theory and Zimmerman's SRL model, data collection integrated preintervention and postintervention self-efficacy ratings, lecturer-assessed design scores, SRL microanalytic interviews, multistakeholder focus groups, and lecturer feedback. The findings suggest that immersive holographic visualization and shared review supported the recalibration of students' academic self-efficacy by connecting confidence judgments more closely to visible performance evidence and lecturer feedback. Qualitative evidence also indicated that students entered the MR environment with uneven levels of prior exposure to augmented reality (AR) and virtual reality (VR) technologies, which appeared to shape their initial technological readiness, cognitive load, and strategic engagement. Participants and lecturers also emphasized the high financial and pedagogical demands of HoloLens 2 implementation. The chapter therefore argues that MR should not be treated as an isolated instructional tool, but as a financially enabled learning infrastructure whose educational value depends on intentional pedagogical scaffolding, digital-readiness support, and sustained curriculum integration.

Keywords: mixed reality, self-regulated learning, academic self-efficacy, engineering education, education finance, digital literacy

1. Introduction

Investing in higher education is fundamentally an investment in human capital. Modern universities continuously allocate significant financial resources toward advanced digital infrastructure, intending to cultivate highly skilled, industry-ready graduates. However, macrolevel analyses of education finance frequently overlook the microlevel psychological realities of student development. When an institution funds a cutting-edge technological intervention, that financial decision directly shapes the immediate learning environment, which in turn influences students' academic beliefs, cognitive bandwidth, and core competencies. To understand the true developmental return on these financial investments, it is necessary to examine how students navigate these high-tech environments at a psychological level. Self-regulated learning (SRL) offers a critical lens for this examination.

Within social cognitive theory, SRL is conceptualized as an agentic process through which learners actively regulate their thoughts, emotions, and behaviors to attain academic goals [1, 2]. From this perspective, SRL is not merely a study skill but a core competence underpinning academic achievement, professional adaptability, and lifelong learning [3]. In cognitively demanding, resource-intensive disciplines such as civil engineering, students must engage in complex problem-solving, integrate abstract spatial representations, and adapt strategies in response to feedback. These demands place substantial pressure on learners' self-regulatory capacity. Research consistently shows that many undergraduates struggle to regulate their learning effectively, facing cognitive, motivational, and socio-emotional hurdles such as weak task understanding, limited metacognitive monitoring, reduced persistence, and academic burnout [4, 5]. Students experiencing these metacognitive and motivational difficulties are more likely to achieve lower grade point averages and face an increased risk of course failure or withdrawal [6].

From a social cognitive perspective, these challenges can be understood through triadic reciprocal causation, whereby personal factors (e.g., motivational beliefs), behavioral outcomes (e.g., academic performance), and environmental conditions interact continuously. Academic self-efficacy, learners' beliefs in their capability to organize and execute actions required for success [7], plays a central role here. Importantly, academic self-efficacy does not operate independently of context; its development depends on how learners interpret feedback within specific environmental constraints. Emerging financial investments in educational technology, such as mixed reality (MR) ecosystems, create new environmental conditions for learning. Mixed reality provides immersive, spatially rich representations and interactive feedback that may reshape how learners plan, monitor, and reflect. At the same time, such high-cost infrastructure introduces new cognitive and technical demands, requiring learners to manage unfamiliar interaction modalities while engaging with disciplinary tasks. Students' readiness to benefit from MR may therefore depend partly on their prior exposure to augmented reality (AR) and virtual reality (VR) technologies and related forms of digital experience. Although such prior exposure may be associated with broader patterns of access and resource distribution, this study does not directly measure socioeconomic status. Accordingly, the chapter treats technological readiness as the

directly observed condition and discusses socioeconomic implications cautiously as a broader interpretive concern.

To bridge the gap between institutional macrofinance and microlevel student psychology, this chapter presents an instrumental case study situated within the Chang'an–Dublin International College of Transportation (CDIC). We investigate a specific, financially enabled learning infrastructure: a HoloLens 2-supported MR environment deployed for undergraduate civil engineering students. Rather than viewing the HoloLens 2 merely as a pedagogical tool, this study conceptualizes it as a significant capital investment intended to function as a developmental incubator.

Building on Zimmerman's SRL model, the purpose of this case study is to explore the lived, microlevel realities of students interacting with a financially enabled MR learning environment. Specifically, the study examines how learners interpret MR-mediated feedback, including real-time visualization and instructor guidance delivered through shared holographic review, and how participation in this environment shapes the calibration of academic self-efficacy, performance, and strategic regulation. By analyzing this bounded case, the chapter highlights how prior technological exposure, pedagogical design, and institutional investment interact in shaping the educational value of MR-supported learning. Where socioeconomic implications are discussed, they are treated as cautious inferences related to unequal access to advanced technologies rather than as directly measured participant characteristics.

2. Theoretical foundations and conceptual framework

2.1 Social cognitive theory within financed learning environments

This chapter is grounded in social cognitive theory, which conceptualizes human learning as an agentic, goal-directed process shaped through reciprocal interactions among personal, behavioral, and environmental factors [1, 8]. From this perspective, learners are not passive recipients of external stimuli but active agents who intentionally regulate their thoughts, motivations, and actions in pursuit of meaningful goals.

Within this framework, human agency is exercised and developed through triadic reciprocal causation, where personal beliefs, behavioral actions, and environmental conditions continuously influence one another. While educational psychology frequently examines the personal and behavioral dimensions of this triad, the *environmental* dimension in modern higher education is fundamentally dictated by institutional finance. The learning environments students operate within – particularly those featuring advanced digital infrastructures – are not naturally occurring; they are the direct materialization of macrolevel financial investments.

Consequently, student agency is exercised within structurally financed boundaries. Regulatory actions depend on how effectively learners interpret feedback, evaluate progress, and respond to contextual affordances and constraints [9]. We conceptualize the HoloLens 2-supported MR environment not merely as a neutral instructional backdrop, but as a financially enabled developmental

incubator. This incubator actively alters the reciprocal system, placing new cognitive, regulatory, and technical demands on the learner.

2.2 Zimmerman's SRL model and cognitive load

Self-regulated learning represents the core mechanism through which learners enact agency in educational contexts. Rooted in social cognitive theory, SRL describes a proactive process where learners use cognitive and metacognitive strategies, respond to feedback, and adapt their behaviors to attain academic goals [2].

Zimmerman's widely adopted process model [10] conceptualizes SRL as a cyclical system comprising three phases (**Figure 1**): forethought, performance, and self-reflection.

- **Forethought** involves goal setting, strategic planning, and self-efficacy judgments that shape readiness for action.
- **Performance** demands the implementation of strategies, regulation of effort, and metacognitive monitoring.
- **Self-reflection** involves self-evaluation, causal attribution, and adaptive inferences that inform future learning cycles.

While SRL skills develop gradually through experience and guided practice [11], introducing high-cost, hyper-advanced technologies into the performance phase can significantly disrupt this regulatory cycle. Navigating an immersive holographic environment requires dedicated cognitive resources. If students must expend

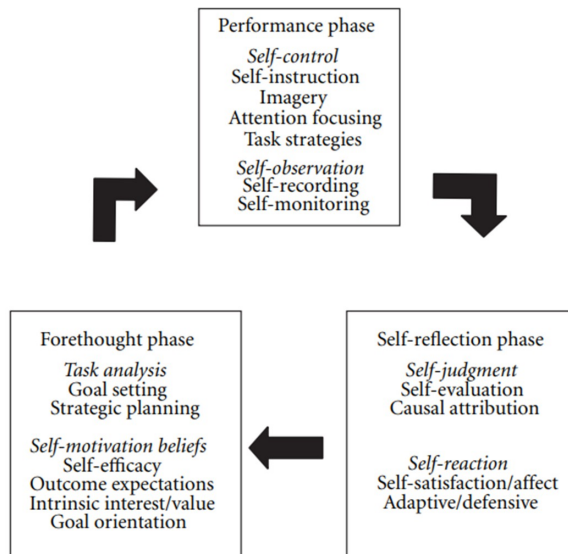


Figure 1.
Zimmerman's three-phase self-regulated learning model.

significant cognitive effort simply to operate the device, their capacity to strategically regulate their learning within the actual academic task is fundamentally compromised.

2.3 The economics of MR: Socioeconomic baselines and digital literacy

To bridge the gap between educational finance and student development, it is important to recognize that a financially enabled MR environment may not be experienced uniformly by all learners. Holographic MR hardware, such as HoloLens 2, represents a substantial capital expenditure for institutions and remains relatively inaccessible for many individual consumers. As a result, students may enter MR-supported learning environments with different levels of prior exposure to AR/VR technologies and different degrees of comfort with immersive digital interfaces.

The present study directly examines students' reported prior exposure to AR/VR technologies and their experiences of technological readiness within the MR task. It does not directly measure socioeconomic status, family income, or household access to digital resources. Therefore, the chapter avoids treating socioeconomic background as an empirical variable in the case. Instead, it focuses on prior technological exposure as the measured contextual condition, while acknowledging that such exposure may reflect broader inequalities in access to advanced digital technologies.

This distinction is methodologically important. Students with greater prior familiarity with immersive technologies may be able to move more quickly beyond basic device operation and use MR as a resource for task monitoring, error detection, and design refinement. Students with limited prior exposure may first need to manage the novelty of the interface, headset operation, spatial navigation, and interpretation of immersive visual feedback. In such cases, cognitive resources may initially be directed toward technological adjustment before they can be fully directed toward disciplinary self-regulation.

Accordingly, this chapter uses the concept of technological readiness to describe students' starting points in the MR environment. The concept captures observable differences in prior exposure, confidence with immersive interfaces, and ability to translate holographic feedback into task-relevant action. The broader socioeconomic significance of these differences is discussed cautiously, not as a direct finding about participants' socioeconomic status, but as an implication for institutions considering expensive educational technologies that may not meet all learners at the same baseline of digital experience.

2.4 Academic self-efficacy and the misalignment of performance

A central determinant of effective self-regulation within this ecosystem is academic self-efficacy – learners' judgments regarding their capability to successfully organize and execute the actions needed to attain specific goals, for example [8]. While academic self-efficacy broadly correlates with higher academic performance, persistence, and strategic engagement, this relationship is not unconditionally stable.

Misalignments frequently occur when learners encounter unfamiliar, heavily mediated learning environments. In these settings, a student's high academic self-efficacy might not translate into immediate performance if they lack the interpretive

resources (such as digital literacy) required to manage cognitive load and adapt their strategies. Alternatively, the immersive feedback provided by MR might expose gaps in a student's spatial reasoning, temporarily depressing their confidence while functionally improving their work. This chapter examines how this heavily financed MR environment initially disrupts and subsequently helps recalibrate this critical efficacy-performance relationship over time.

2.5 Conceptual framework: Exploring the bounded case

Synthesizing these perspectives, this chapter's conceptual framework positions institutional investment in MR infrastructure as a catalyst that triggers a complex interplay among technological readiness, academic self-efficacy, academic performance, and SRL. Rather than isolating MR as a distinct instructional variable intended to produce generalized statistical outcomes, the framework supports an exploratory case study of the lived, microlevel realities of civil engineering students at CDIC. Guided by this framework, the subsequent sections of this chapter will explore three core dimensions of this bounded case:

- (1) **Recalibration of efficacy and performance:** How engagement within the HoloLens 2-supported environment shaped, disrupted, and recalibrated students' academic confidence and task performance?
- (2) **Technological readiness and SRL:** How do students' reported prior exposure to AR/VR technologies and their initial comfort with immersive interfaces shape digital readiness, cognitive load, and strategic adaptation across Zimmerman's three SRL phases?
- (3) **The pedagogy-investment paradigm:** How did students and lecturers perceive the financial and pedagogical demands of HoloLens 2 implementation, and what forms of instructional scaffolding were required for this capital investment to support meaningful and equitable student development?

3. Methodology: A mixed-methods case study design

This research employs an instrumental mixed-methods case study design [12, 13] to examine the lived microlevel realities of students and educators interacting with a high-cost educational technology intervention. Rather than seeking statistically generalizable outcomes across a broad population, this approach investigates a specific, bounded system in order to generate nuanced insights into complex socio-technical and pedagogical phenomena [13].

The case is bounded by its context, participants, task, and technological infrastructure: specifically, the intersection of eight undergraduate civil engineering students and three course lecturers at the CDIC, an authentic Revit-based civil engineering design task, and their collective interaction with a HoloLens 2-supported MR learning environment.

Within this bounded case, quantitative measures of academic self-efficacy and academic performance are not used for inferential statistical claims. Instead, they serve as descriptive case data at the individual and group levels. These quantitative

tracking points establish the “descriptive what” by indicating shifts in confidence beliefs and rubric-based achievement before and after the intervention. The qualitative data, comprising SRL microanalytic interviews, multistakeholder focus groups, and structured lecturer feedback, explore the “how” and “why” by triangulating the quantitative data to reveal how cognitive bandwidth, technological readiness, instructional scaffolding, and MR affordances shaped students’ SRL and design development.

3.1 Participants and contextual boundaries

The primary cohort comprised eight third-year undergraduate civil engineering students aged 20 to 22 years enrolled at CDIC. In addition, three civil engineering lecturers participated in the study to provide instructional feedback, model evaluation, and multistakeholder perspectives on the pedagogical integration of the technology. The study submission was reviewed by the University Human Research Ethics Committee and deemed low risk. All students and lecturers provided informed consent prior to data collection.

A key contextual feature of the case was participants’ uneven but generally limited prior exposure to immersive technologies. Although some students had encountered AR, VR, or related technologies, such experience was generally informal and entertainment-oriented rather than academic, technical, or engineering-specific. This limited baseline of MR-specific digital literacy was treated as an important contextual condition for interpreting students’ initial technological readiness, cognitive load, and strategic engagement. Because the study did not directly collect socioeconomic status data, prior exposure to immersive technologies was not treated as a proxy measure of socioeconomic background. Instead, it was analyzed as a directly reported feature of students’ technological experience, with broader equity implications discussed cautiously.

4. Data collection and instruments

Data were collected through a concurrent mixed-methods strategy designed to capture the reciprocal relationships among personal beliefs, behavioral performance, instructional scaffolding, and the MR learning environment. The quantitative component comprised preintervention and postintervention academic self-efficacy ratings and lecturer-assessed design performance scores. The qualitative component comprised SRL microanalytic interviews, four multistakeholder focus groups, and written and verbal lecturer feedback generated during shared holographic model reviews.

Academic self-efficacy was measured before and after the intervention using a single-item confidence rating adapted from Bandura’s self-efficacy measurement framework [14]. Academic performance data were collected from lecturers’ assessments of students’ design models before and after the intervention. The same rubric criteria were applied across both assessment points to support descriptive comparison. Qualitative data were gathered through semi-structured SRL microanalytic interviews aligned with Zimmerman’s forethought, performance, and self-reflection phases, and through focus groups involving all eight students and the three lecturers.

The interviews and focus groups were conducted in Mandarin. Approximately seven hours of audio and video data were recorded, transcribed verbatim, translated into English, and checked through bilingual verification to reduce the risk of cross-language distortion. Rather than treating the quantitative and qualitative data streams as separate strands, they were integrated during interpretation so that changes in self-efficacy and performance could be examined alongside students' accounts of strategy use, technological challenges, error detection, feedback interpretation, and confidence recalibration.

4.1 Descriptive quantitative case measures

4.1.1 Academic self-efficacy scale

Students' academic self-efficacy was measured using a single-item confidence rating adapted from Bandura's self-efficacy measurement framework [14]. Participants rated their confidence in completing a civil engineering design task with strong academic performance on a 0–100 confidence scale. The item was administered before and after the intervention.

The preintervention item asked:

"On a scale from 0 to 100, where 0 means 'not sure at all,' 40 means 'somewhat sure,' 70 means 'pretty sure,' and 100 means 'very sure,' how sure are you that you can complete the civil engineering design task with strong academic performance?"

The postintervention item asked:

"On a scale from 0 to 100, where 0 means 'not sure at all,' 40 means 'somewhat sure,' 70 means 'pretty sure,' and 100 means 'very sure,' how sure are you that you can complete civil engineering design tasks with better academic performance in the future?"

Students were explicitly encouraged to select any value between the anchor points to represent their perceived capability as precisely as possible. This approach is consistent with Bandura's recommendation that efficacy beliefs should be measured with task-specific, gradated confidence scales rather than broad or decontextualized items. Higher scores indicated a stronger perceived capability to achieve successful academic outcomes in the civil engineering design task.

4.1.2 Academic performance assessment

Participants' academic performance was represented using preintervention and postintervention academic scores from the design task marked by the same lecturer. These numerical data were analyzed descriptively using SPSS software, focusing on changes in central tendency and dispersion over time. Specifically, means, standard deviations, academic score rankings, and rank changes were computed to summarize overall trends and individual-level patterns before and after the HoloLens 2 intervention.

The original 100-point rubric covered terrain-based modeling and route selection, model rendering and aesthetics, structural analysis and design, bridge elevation design, presentation clarity, and discussion and reflection. For this study, these criteria were organized into four broader dimensions: accuracy, completeness, creativity, and technical feasibility. Accuracy captured the correctness of the model in relation to task requirements, spatial relationships, dimensions, and engineering logic. Completeness referred to the inclusion of

required bridge components, structural elements, and task-specific deliverables. Creativity reflected thoughtful design decisions, problem-solving, rendering quality, and aesthetic presentation. Technical feasibility captured the structural plausibility, standards compliance, clarity of presentation, and students' ability to justify and reflect on their design decisions. Lecturer-assigned scores were used as descriptive indicators of academic performance rather than for inferential statistical testing.

The purpose was to identify individual and group-level changes in design performance and to triangulate those changes with students' accounts of strategy use, error detection, confidence recalibration, and lecturer feedback.

4.2 Qualitative triangulation

4.2.1 SRL microanalytic interviews

Semi-structured interviews followed the SRL Microanalysis Protocol, defined as "a strategic, coordinated plan of administering context-specific questions targeting multiple cyclical phase subprocesses as students engage in authentic activities" [15]. This protocol (see **Figure 2**) was selected because it is specifically designed to examine how learners approach, perform, and reflect on authentic learning tasks across the cyclical phases of SRL. The interview protocol was aligned with Zimmerman's three-phase model: forethought, performance, and self-reflection.

Forethought questions were administered before students engaged in the MR-supported task and focused on goal setting, task understanding, prior experience, strategic planning, and initial confidence. Performance questions were administered during the modeling and visualization process and focused on monitoring, strategy use, cognitive load, attention management, technical difficulties, and error detection. Self-reflection questions were administered after the shared holographic review and focused on students' self-evaluation, interpretation of feedback, perceived causes of success or difficulty, confidence recalibration, and intended future strategy use.

The semi-structured format ensured consistency across interviews while allowing participants to elaborate on personally meaningful aspects of their experience. Example areas of questioning are summarized below in **Table 1**.

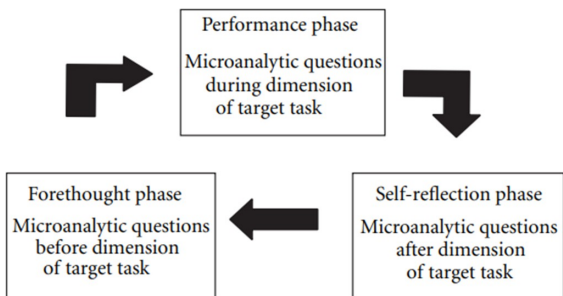


Figure 2.
SRL microanalysis loop of task phase.

SRL phase	Interview focus
Forethought	Students' goals, expectations, prior experience with AR/VR/MR technologies, perceived task demands, and planned strategies
Performance	Students' monitoring processes, movement between Revit and HoloLens 2, error detection, spatial reasoning, cognitive load, technical challenges, and strategy adjustment
Self-reflection	Students' evaluation of model quality, interpretation of lecturer feedback, perceived learning gains, confidence recalibration, and future strategy revision

Table 1.

Summary of semi-structured interview focus across the three phases of self-regulated learning.

4.2.2 Multistakeholder focus groups

Four focus-group interviews were conducted with the eight student participants and three lecturers. These focus groups provided an opportunity to collaboratively interpret findings emerging from the self-efficacy ratings, performance scores, microanalytic interviews, and MR-supported design activities. They also enabled comparison between student and lecturer perspectives on the pedagogical value, practical constraints, and financial implications of using HoloLens 2 in civil engineering education.

The focus-group protocol addressed three main areas. First, participants discussed their SRL experiences during the intervention, including planning, monitoring, error correction, help-seeking, feedback use, and reflection. Second, they considered the affordances and constraints of the MR environment, including spatial visualization, immersive inspection, collaboration, cognitive load, technical readiness, and the transition between Revit and HoloLens 2. Third, they examined the cost-benefit implications of the HoloLens 2 ecosystem, including whether the observed pedagogical benefits justified the financial, logistical, and instructional investment required for implementation.

4.2.3 MR-mediated lecturer feedback

During the self-reflection phase, lecturers reviewed students' postintervention models through a shared HoloLens 2 holographic review. Students presented their models in the shared MR environment, using holographic visualization to communicate design rationale, mentally and verbally revisit model features, respond to lecturers' questions, and reflect on the strengths and limitations of their work.

Lecturers provided both written and verbal feedback. Feedback addressed structural completeness, dimensional accuracy, standards compliance, technical feasibility, design presentation, and overall model quality. Lecturers also assigned postintervention scores using the same rubric applied to the preintervention submissions. This feedback functioned as external evaluative evidence and was triangulated with students' self-reports to examine how learners interpreted feedback, identified discrepancies, revised strategies, and recalibrated academic self-efficacy.

4.3 Qualitative data analysis

The qualitative data were analyzed using a theory-informed thematic coding procedure supported by NVivo. Audio and video recordings from the interviews and

focus groups were transcribed verbatim in Mandarin and translated into English. Bilingual verification was undertaken to check the accuracy and conceptual equivalence of the English translations against the original Mandarin transcripts.

All focus group interviews were video-recorded via Zoom. The recordings were transcribed verbatim in Mandarin and then translated into English. The translated transcripts underwent intercoder reliability checks done by another PhD researcher before being imported into NVivo for coding and analysis. A six-phase reflexive thematic analysis was undertaken to explore patterned meanings across the dataset [16, 17]. Although these six phases are conceptually distinct, they are recursive, requiring continuous movement between phases in a spirit of inquiry and interpretation [17]. During the analysis, we worked with the digital transcripts, recognizing that shifting between media formats often prompts new reflections, insights, and interpretations. Each transcript was reviewed multiple times, during which quotes relevant to the research questions were identified. These quotes

were then grouped and regrouped based on conceptual similarities and differences. The resulting categories were continuously compared against the original data, enabling refinement and reorganization until a stable categorical system emerged. From this process, final descriptive categories were formulated, representing the most salient and meaningful features of the data.

To strengthen analytic transparency, coding decisions were documented throughout the analysis process. Translated transcripts were checked for consistency, coded excerpts were repeatedly compared with their surrounding context, and developing categories were revised where necessary to avoid premature closure. The final themes were generated through iterative engagement with the full dataset and were used to explain how the MR intervention mediated students' SRL processes within the civil engineering design task.

4.4 The MR environment as a developmental incubator

The technological boundary of the case was defined by the HoloLens 2 headset running the BIM Holoview application. This infrastructure enabled students to import, project, inspect, and discuss their BIM/Revit models in physical space through collaborative table-top projection and full-scale 1:1 immersive walkthroughs.

These spatial affordances altered the learning environment in several important ways. They enabled students to evaluate spatial relationships, adjust architectural transparency, inspect models from multiple perspectives, and identify discrepancies that were often less visible in conventional 2D drawings or desktop-based 3D views. Examples included spatial misalignments, missing structural elements, dimensional inconsistencies, and weaknesses in the relationship between design components. The platform also supported real-time annotation and screen capture, enabling students and lecturers to connect immersive inspection with concrete design evidence.

In this study, the MR environment was therefore conceptualized not only as a visualization tool but also as a developmental incubator for SRL. It created opportunities for students to plan design strategies, monitor progress, identify errors, seek feedback, and revise their work through repeated interaction with both the digital model and the physical learning environment.

4.5 Case study procedure: Scaffolding the SRL cycle

The HoloLens 2 intervention lasted approximately two months and was structured around the three cyclical phases of SRL: forethought, performance, and self-reflection, based on Zimmerman's triadic SRL model. This sequence was designed to support students' movement from initial task understanding and goal setting, through iterative design monitoring and model refinement, to final evaluation, feedback interpretation, and strategy revision.

4.5.1 Forethought phase

The intervention began with an approximately one-hour introductory session. During this session, students were introduced to the HoloLens 2 headset and the BIM Holoview application. They examined preloaded immersive holographic models, including a demonstration building (see **Figure 3**) and a functioning bridge (**Figure 4**). These visualizations served as cognitive anchors, helping students activate prior knowledge, understand the design task, anticipate the affordances of MR visualization, and begin planning their own Revit modeling strategies.

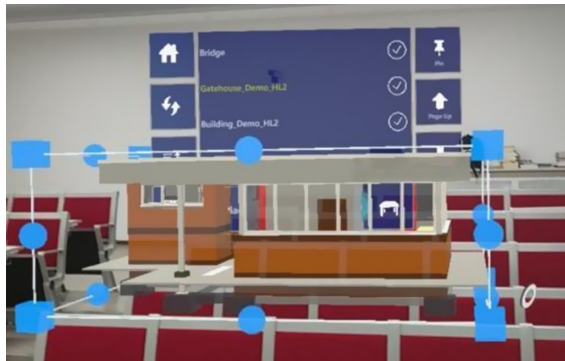


Figure 3.
Holographic view of the demonstration building model.



Figure 4.
Holographic view of the demonstration bridge model.

Students also completed the preintervention academic self-efficacy confidence rating during this phase. Forethought-phase microanalytic prompts explored students' initial goals, confidence beliefs, perceived task demands, prior experience with AR/VR/MR technologies, and intended strategies for completing the civil engineering design task.

4.5.2 Performance phase

After the introductory session, students returned to Revit to develop their own civil engineering design models. Across the main two-month intervention period, students engaged in an iterative cycle of model construction, MR visualization, error checking, and model revision. They uploaded their Revit models to the HoloLens 2 environment, inspected them through holographic table-top projection and full-scale immersive walkthroughs, identified errors or areas for improvement, returned to the computer to modify their Revit models, and then reuploaded the revised versions for further inspection. This process continued until students were satisfied with the accuracy, completeness, and presentation quality of their models.

This phase constituted the central performance stage of the intervention. The repeated transition between Revit and HoloLens 2 required students to monitor both disciplinary content and technological operation. They had to manage the cognitive demands of using the headset while simultaneously evaluating spatial relationships, checking structural components, detecting missing or misaligned elements, and revising design decisions. Performance-phase microanalytic prompts therefore focused on students' monitoring processes, strategy adjustment, attention management, perceived cognitive load, technical difficulties, and error-detection practices.

4.5.3 Self-reflection phase

The intervention concluded with an approximately one-hour shared holographic review involving students and lecturers. During this session, students presented their final models through the HoloLens 2 environment. The shared holographic experience provided a common spatial reference point for discussing design rationale, revisiting model features, identifying strengths and weaknesses, and evaluating the effectiveness of students' design decisions.

Lecturers provided detailed written and verbal feedback on each model. Their feedback addressed accuracy, completeness, creativity, technical feasibility, standards compliance, and presentation quality. They also assigned postintervention model scores using the same rubric applied to the preintervention submissions. Following this review, students completed the postintervention academic self-efficacy confidence rating and participated in self-reflection interviews exploring perceived learning gains, feedback interpretation, confidence recalibration, and intended future strategy use.

By structuring the intervention across these three phases, the study operationalized the HoloLens 2-supported MR environment as a scaffold for triadic SRL. Students were guided to set goals, enact strategies, monitor progress, detect errors, interpret feedback, and revise future approaches within an authentic civil engineering design context. This procedure also strengthened methodological

transparency by linking the intervention duration, task sequence, measurement points, interview timing, lecturer assessment, and qualitative interpretation directly to the SRL framework.

5. Findings

This bounded case suggests that the educational significance of HoloLens 2 lay not simply in its novelty as an immersive device, but in how it reconfigured the relationship among academic confidence, task performance, technological readiness, and pedagogical support within a civil engineering learning environment. In keeping with the conceptual framework outlined earlier, the findings are organized around three interrelated dimensions of the case: recalibration of efficacy and performance, technological readiness as a mediator of SRL, and the pedagogy-investment paradigm. Across these dimensions, the evidence suggests that MR functioned less as a stand-alone instructional variable than as part of a broader, financially enabled learning environment whose developmental significance depended on how students interpreted immersive feedback and how lecturers scaffolded that interpretation.

5.1 Recalibration of efficacy and performance

The first dimension of the case concerns how participation in the HoloLens 2-supported environment appeared to unsettle and then partially recalibrate the relationship between academic self-efficacy and academic performance. The descriptive quantitative data provide an initial indication of this pattern.

Table 2 shows that at the group level, mean academic self-efficacy increased from 75.00 before the intervention to 92.50 afterward, while the standard deviation decreased from 18.52 to 11.65. Academic performance showed a smaller descriptive shift, from a mean of 84.50 to 87.25, with the standard deviation declining from 7.13 to 4.17. These figures are illustrated as descriptive markers within this cohort. They are consistent with the possibility that students’ confidence ratings became higher and less dispersed, while performance outcomes became more even following the intervention.

The individual-level profiles provide a more textured picture in **Table 3**. Before the intervention, six of the eight student participants displayed inverse or otherwise uneven patterns between academic self-efficacy and academic performance. After the intervention, five showed co-occurring high self-efficacy and high academic scores. Within this case, this points to a tendency for confidence

	Before the intervention of HoloLens 2		After the intervention of HoloLens 2	
	Self-efficacy	Academic score	Self-efficacy	Academic score
Mean	75.00	84.5	92.50	87.25
Standard deviation	18.5164	7.1314	11.6496	4.1662

Table 2.
Mean and standard deviation of self-efficacy and academic scores before and after the intervention with HoloLens 2.

Before the intervention of HoloLens 2			After the intervention of HoloLens 2		Rank difference in academic scores before and after
Participant ID	Academic SE	Rank of academic score	Academic SE	Rank of academic score	
P1	70	3	90	2	1
P2	70	2	100	1	1
P3	70	1	70	2	-1
P4	40	3	100	7	-4
P5	90	5	70	8	-3
P6	70	7	100	6	1
P7	100	8	100	5	3
P8	90	6	100	4	2

Table 3.
Academic self-efficacy, the rank of academic scores, and the rank difference of academic scores before and after the intervention with HoloLens 2.

and performance to appear more coherent for several participants after MR-supported engagement.

The qualitative material helps explain how this recalibration may have occurred. In the forethought phase, many students described expected performance in relatively abstract terms, often drawing on prior desktop-based modeling experience, general readiness, or assumptions about what the task would require. At this stage, confidence often preceded direct immersive evidence. By the self-reflection phase, however, students' accounts suggest that confidence was increasingly tied to completed work, visible inspection, and explicit checking against standards.

Participant 2, for example, described the holographic projection as producing a "sense of accomplishment" that "motivates me to learn and do more" (S3). What matters here is less the positivity of the statement than its grounding in reviewed work. Confidence, in this instance, appeared to emerge through completion and inspection rather than anticipation alone. Participant 1 similarly explained that HoloLens 2 enabled checking "after completion to ensure its accuracy" and thereby saved time (S3), suggesting that confidence had become connected to verification rather than impression.

This shift did not always take the form of simple confidence gain. For some students, the process appeared to produce a more qualified and disciplined form of self-belief. Participant 7 moved from initial enthusiasm about being able to view the model "from various angles" (S1) to a more measured confidence grounded in recognizing areas that still required improvement, especially internal structures (S2). In such cases, postintervention confidence may not have become uniformly stronger, but it may have become more credible because it was more closely tied to evidence of adequacy and limitations.

Lecturer feedback appears to have reinforced this process by clarifying what counted as acceptable quality. Comments that a model was "relatively complete" but still required more rational column placement, stronger structural detailing, or improved dimensional accuracy gave students a more concrete evaluative frame for judging their own work. Within this case, then, the first conceptual

dimension – recalibration of efficacy and performance – is reflected less in a dramatic outcome change than in an observable shift from assumption-based confidence toward more evidence-based self-judgment.

5.2 Technological readiness as a mediator of SRL

The second dimension of the case concerns how students' prior exposure to immersive technologies appeared to shape their technological readiness, engagement, and strategic adaptation across the SRL cycle. Most participants reported little prior exposure to AR or VR, and where such exposure existed, it was generally limited to entertainment rather than academic or technical use. Within this small case, these differences appeared to matter because the HoloLens 2 environment introduced not only a new tool but also a new interpretive demand. Students had to navigate spatially immersive information while simultaneously regulating their learning within a disciplinary design task.

In the forethought phase, prior familiarity with immersive environments appeared to influence students' initial orientation to the task. For some students, the novelty of the device and interface formed part of the challenge itself. They were not simply preparing to complete a civil engineering modeling task; they were also adapting to a technologically unfamiliar environment. Under such conditions, strategic planning could not be separated from technological adjustment. This suggests that SRL in MR contexts may begin from uneven starting points, even before the substantive task is fully underway.

In the performance phase, these differences became more visible in the ways students used the environment. Some students appeared able to incorporate the holographic interface relatively quickly into active monitoring and revision. Participant 3, for instance, described being able to “walk through” the model, inspect it “layer by layer,” and identify beam-column misalignment and missing railings in ways that were not possible from the “fixed angles” available on a conventional computer screen (S2). In this account, MR appears to have become a functional diagnostic resource within strategic monitoring.

For other students, however, the immersive environment required a more demanding interpretive transition. Participant 4's account is particularly illustrative. Entering the virtual room revealed that the proportions “weren't quite right” and that, compared with real-life spaces, the layout did not feel appropriate, with too much emphasis on entertainment and insufficient attention to comfort (S2). This realization was productive, but it also indicates a more effortful process of learning how to translate immersive perception into disciplinary judgment. By the self-reflection phase, the participant had linked these shortcomings to absent stairs for emergency escape, missing drainage, and roofs without eaves, interpreting them as signs of gaps in architectural knowledge rather than as isolated technical flaws (S3). The developmental value of the experience was evident, but it emerged through adaptation rather than immediate fluency.

These contrasts suggest that prior exposure to immersive technologies may have shaped the ease with which students moved through Zimmerman's phases of forethought, performance, and self-reflection. Those with greater baseline familiarity appeared better positioned to use MR as a learning aid from the outset, whereas those with less prior exposure seemed to require a preliminary stage of adjustment before the environment could function strategically. This finding should

be interpreted cautiously. The study did not directly measure socioeconomic status, family income, or household technology access, and therefore cannot establish a causal relationship between socioeconomic background and SRL performance. What the case suggests more directly is that uneven prior exposure to immersive technologies shaped students' technological readiness, which in turn appeared to influence how readily they could use MR for SRL.

The HoloLens 2-supported environment did not present itself to all students in the same way. Its developmental potential appeared to be mediated by differing levels of technological readiness, interpretive confidence, and comfort with immersive feedback. In this sense, the second conceptual dimension is reflected in the finding that students' entry points into MR-supported self-regulation were uneven. The broader socioeconomic significance of this pattern lies not in direct evidence about participants' backgrounds, but in the implication that costly educational technologies may require explicit readiness support if they are to benefit students equitably.

5.3 The pedagogy-investment paradigm

The third dimension of the case concerns the relationship between costly technological infrastructure and the pedagogical conditions required for it to become educationally meaningful. Here, the evidence suggests that the value of HoloLens 2 did not lie in the hardware alone, but in the extent to which its use was accompanied by structured guidance, shared review, and standards-based instructional mediation. In this sense, the findings point toward a pedagogy-investment paradigm in which technological expenditure becomes educationally significant only when matched by deliberate pedagogical support.

One important aspect of this theme emerged from the role of shared holographic review. Students did not appear to benefit simply from seeing their models in immersive form. Rather, the educational usefulness of the experience depended on having those visualizations interpreted through disciplinary expectations. Lecturer feedback anchored model inspection in criteria such as structural completeness, dimensional accuracy, standards compliance, and presentation quality. This helped transform the holographic environment from an impressive interface into a pedagogical space for evaluative dialog.

The lecturers' role was therefore not incidental, but central. In several cases, the MR environment made discrepancies more visible, but it was lecturer feedback that helped students classify those discrepancies as meaningful engineering problems rather than as vague perceptions that something was wrong. Suggestions to add auxiliary bridge elements, verify abutment dimensions, improve column placement, refine detailing, or address contextual issues such as drainage and canopies showed how pedagogical mediation translated immersive perception into disciplinary refinement.

The focus-group material also points in this direction. Both students and lecturers appeared to view HoloLens 2 as valuable but not self-sufficient. Students tended to value the technology for its realism, inspection capacity, and relevance to future professional settings, while also implying that such environments require support if learners are to move beyond novelty into purposeful engagement. Lecturers, meanwhile, emphasized that MR becomes educationally useful only when carefully integrated into task design, review processes, and disciplinary expectations. Across

these perspectives, the case suggests a shared recognition that high-cost MR hardware cannot function effectively as an isolated intervention.

Therefore, the HoloLens 2-supported SRL context should not be understood as a one-off purchase whose educational value is automatically realized upon deployment. Rather, within this case, its value appeared to depend on accompanying investments in training, curriculum integration, teacher–student interaction beyond the classroom, and scaffolding. Without such supports, technologically advanced environments may remain symbolically innovative without becoming developmentally effective.

The pedagogy-investment paradigm also helps explain why the case showed stronger signs of confidence recalibration and reflective awareness than of large performance shifts. The technology appeared to make performance evidence more visible, but its developmental usefulness depended on how that visibility was pedagogically organized. In this respect, the third conceptual dimension is reflected in the finding that infrastructure alone was insufficient; what mattered was the alignment between financial investment and pedagogical design.

5.4 Cross-case synthesis

Taken together, the three dimensions of the case suggest that the HoloLens 2-supported environment influenced learning not through a simple treatment effect, but through a developmental sequence shaped by evidence, readiness, and mediation. Students entered the intervention with uneven confidence, differing levels of prior technological familiarity, and often imperfect alignment between what they believed they could do and what their work actually demonstrated. The MR environment then made structural omissions, spatial inconsistencies, and realism problems more visible. Through shared holographic review and lecturer feedback, these observations were translated into standards-based judgments and opportunities for revision.

Within this process, academic self-efficacy appeared to become more evidence-based, performance refinement became more targeted, and the importance of technological readiness became more visible. At the same time, the case suggests that these developments were neither automatic nor uniform. The developmental significance of MR depended on the interaction among prior technological exposure, interpretive capacity, instructional scaffolding, and the broader institutional commitment required to support their alignment.

In this sense, the findings correspond closely to the chapter's conceptual framework. They suggest that institutional investment in MR infrastructure may shape student development, but only through the complex interplay among efficacy recalibration, technological readiness, and pedagogical mediation. HoloLens 2 did not simplify the complexity of engineering learning; rather, it made that complexity more visible and, under supportive conditions, more learnable.

6. Discussion

The case suggests that the educational value of HoloLens 2 cannot be understood simply in terms of technological novelty or short-term performance gain. Rather, its significance lies in how it reconfigured the conditions under which students judged their own capability, interpreted task evidence, and engaged in SRL. Read in relation

to the broader aims of this volume, the case indicates that investment in advanced educational technology is also an investment in the psychological and pedagogical conditions of learning. What matters, therefore, is not only whether institutions acquire innovative hardware, but how such infrastructure becomes developmentally meaningful for students.

6.1 Recalibrating confidence in an immersive learning environment

One of the clearest contributions of the case lies in showing that academic self-efficacy in MR-supported learning is best understood as a process of recalibration rather than simple enhancement. Within this small cohort, the descriptive data suggest that confidence ratings became higher and less dispersed after the intervention, while the qualitative evidence indicates that confidence also became more closely tied to visible task evidence and standards-based evaluation. Taken together, these findings suggest that the HoloLens 2-supported environment did not merely make students feel more confident; it may have helped some of them judge their capability more carefully and on a more evidence-based basis.

This distinction is important in relation to social cognitive theory. Bandura's account of self-efficacy emphasizes that efficacy beliefs are shaped not only by success or failure in abstract terms, but also by how individuals interpret mastery experiences and feedback. In the present case, mastery seemed to involve more than task completion. It also involved the ability to inspect one's work, confront discrepancies, and evaluate adequacy against visible and shared criteria. Confidence, in this sense, was not simply strengthened by participation; it was subjected to a more demanding evaluative process.

This helps explain why some students' postintervention confidence appeared more conditional than simply more positive. In immersive environments, confidence may become more educationally productive precisely when it is less impressionistic and more accountable to evidence. That point matters for engineering education, where misplaced confidence can be as problematic as low confidence. The case, therefore, suggests that MR may support a form of self-efficacy development that is not only motivational but also disciplinary in nature – one that connects belief more directly to adequacy, checking, and professional judgment.

6.2 MR as a medium for performance refinement rather than direct performance gain

The second point emerging from the case concerns the nature of performance change. The descriptive quantitative patterns suggest only modest movement in academic scores, and these should be interpreted cautiously. However, the qualitative evidence indicates that MR contributed to performance not by producing dramatic improvements, but by supporting processes of refinement that are educationally significant, especially in a design-oriented engineering context.

What HoloLens 2 seemed to offer was a different mode of noticing. Spatial inconsistencies, missing structural elements, contextual mismatches, and realism problems became more perceptible in ways that conventional desktop review did not always allow. This altered not only what students saw but how they could act on what they saw. Performance improvement, therefore, appeared to depend less on

immersion alone than on the interplay among immersive inspection, guided interpretation, and iterative revision.

This point has implications for how MR should be evaluated pedagogically. If it is judged only by whether it produces large short-term score gains, its value may appear limited. Yet such an assessment would miss the more subtle developmental contribution suggested by this case: Mixed reality may help make tacit deficiencies visible and therefore available for reflection and correction. In professional disciplines, this kind of refinement may be more important than rapid score increases, because it strengthens the habits of checking, judgment, and revision that underpin later competence.

6.3 Technological readiness and uneven entry points into SRL

A further contribution of the case lies in drawing attention to uneven technological readiness as a condition shaping engagement with MR-supported SRL. Students did not approach the HoloLens 2 environment from identical starting points. Although most had limited prior exposure to immersive technologies, the differences that did exist appeared to matter. Some students seemed able to move relatively quickly from initial orientation to diagnostic use of the technology, while others appeared to require a more substantial period of adjustment before immersive feedback could be used strategically.

This point is analytically important because it complicates any straightforward celebration of immersive learning environments. Mixed reality may expand the possibilities for SRL, but it may also introduce new interpretive demands. Students must not only engage with the academic task; they must also learn how to read, trust, and act upon immersive spatial representations. As the findings suggest, this process is unlikely to be identical for all learners.

Within the boundaries of this case, the chapter's broader concern with educational finance remains relevant. Prior exposure to advanced digital hardware is unlikely to be evenly distributed across all student populations, and differences in such exposure may shape how readily students benefit from institutionally provided infrastructure. In that sense, the case points toward a broader equity issue: High-cost educational technologies may create valuable learning opportunities, but they do not necessarily meet all learners with the same level of prior digital experience.

This observation reinforces the importance of treating digital literacy not as a background skill, but as an active condition of participation in technologically mediated learning. In MR environments, technical fluency, interpretive judgment, and tolerance for uncertainty all appear relevant to how students move through forethought, performance, and self-reflection. The chapter therefore supports a view of digital literacy as intertwined with SRL rather than external to it.

6.4 The pedagogy-investment paradigm

The case also has implications for how institutions understand the relationship between technological investment and teaching practice. The findings suggest that the educational usefulness of HoloLens 2 did not arise from the cutting-edge MR hardware alone. Rather, it emerged through a pedagogically mediated process involving shared review, lecturer feedback, explicit standards, and opportunities for revision. In other words, the technology became meaningful because it was

embedded in a meaningful teaching design that helped students interpret what the immersive environment revealed.

This is where the financial framing of the chapter becomes especially important. An MR device such as HoloLens 2 represents a visible form of institutional investment, but the case suggests that its developmental return depends on less visible accompanying investments: staff time beyond the classroom, curriculum integration, training, guided feedback, and support for learner adjustment. Without these, technologically advanced environments may remain impressive but educationally under-realized.

The focus-group evidence reinforces this point by suggesting that both students and lecturers recognized the value of the technology while also implying that it could not stand alone. Students appeared to value the realism and professional relevance of the environment, whereas lecturers emphasized the need for deliberate integration and interpretive support. Across these perspectives, the case points to a shared recognition that the return on expensive MR infrastructure cannot be assessed in hardware terms alone. It must be understood in relation to the pedagogical ecosystem that surrounds it.

This leads to a broader conceptual implication for the volume. Educational finance is often discussed at the level of access, cost, or resource distribution. This case suggests an additional layer: Financial investment also shapes the microlevel conditions under which students learn to judge, regulate, and improve their own work. From this perspective, investment in MR is not only a technological decision; it is also a developmental and pedagogical one.

6.5 Implications for the conceptual framework and broader significance

Taken together, the discussion supports the three dimensions outlined in the chapter's conceptual framework, but with necessary nuance. First, the case supports the claim that HoloLens 2 participation was associated with a process of efficacy-performance recalibration, although this recalibration should be understood as a descriptive tendency within a small exploratory case rather than as a generalizable effect. Second, the case suggests that prior exposure to immersive technologies shaped students' engagement with MR-supported SRL, although the evidence directly supports the language of technological readiness rather than causal claims about socioeconomic difference. Third, the findings indicate that the value of MR depended on pedagogical mediation, thereby supporting the idea of a pedagogy-investment paradigm. These evidence-based clarifications support the account of how academic confidence, task performance, technological readiness, and pedagogy interacted within a financed immersive learning environment.

For the wider concerns, the case offers a useful microlevel perspective on how financial investment intersects with student development. The chapter does not suggest that MR infrastructure automatically produces better learning outcomes, nor that expensive technologies are inherently transformative. What it does suggest is that institutional spending decisions shape the environments in which students form confidence, respond to feedback, and develop professional habits of mind.

Seen in this light, the significance of educational finance extends beyond questions of access and provision. It also concerns the design of developmental conditions. A high-cost technology may widen possibilities for learning, but whether those possibilities become equitable and educationally productive depends on the

pedagogical structures that accompany them and on the readiness with which students can enter them.

The case therefore supports a broader understanding of educational investment: one in which financial decisions are inseparable from questions of psychological development, technological equity, and the cultivation of resilient, reflective, industry-ready learners.

7. Limitations and implications for future research

Several limitations shape how this case should be interpreted. First, the chapter is based on a small cohort of eight civil engineering students and three lecturers within a single institutional setting. This enabled close attention to lived processes of confidence, feedback, and regulation, but it also limits the range of experiences represented. The value of the case lies in analytic depth rather than breadth.

A further limitation concerns the interpretation of socioeconomic implications. The study collected data on students' reported prior exposure to AR/VR technologies and their experiences of technological readiness, but it did not directly measure socioeconomic status, family income, household technology access, or other indicators of socioeconomic background. Therefore, the chapter does not claim that socioeconomic status directly shaped students' SRL or performance in this case. Instead, it treats uneven prior technological exposure as the directly observed condition and discusses socioeconomic inequality only as a broader implication for institutions investing in expensive educational technologies.

Third, the intervention was relatively short. The study, therefore, captures immediate shifts in confidence, performance, and their apparent relationship, but it cannot show whether these tendencies would persist over time. It remains unclear whether repeated engagement with MR would strengthen the same patterns, reduce initial inequalities in technological readiness, or lead to more durable changes in SRL.

Finally, academic performance was assessed through a single design task. Although this offered a focused view of task-based refinement, it does not capture the full range of competencies relevant to engineering education or longer-term professional development. The findings should therefore be read as specific to this bounded learning context rather than as a comprehensive account of engineering capability.

These limitations also indicate several directions for future inquiry. Longitudinal work would be especially valuable for examining whether the confidence recalibration observed here becomes more stable over time and whether repeated exposure to MR changes how students monitor, revise, and evaluate their work. Such research could also explore whether early differences in technological readiness narrow with continued use or remain influential.

Future research should examine the relationship among socioeconomic background, prior technological exposure, MR-specific digital literacy, and SRL more directly. Larger studies could include measures of household technology access, prior immersive technology experience, digital confidence, and socioeconomic indicators in order to clarify whether and how broader inequalities shape students' readiness to benefit from MR-supported learning environments.

Additionally, the financial dimension deserves more sustained attention than it currently receives in most educational technology research. If MR is to be treated as

developmental infrastructure rather than as a discrete device, future studies should examine not only whether it appears useful but under what institutional, economic, and pedagogical conditions it becomes equitable, sustainable, and educationally meaningful. This would strengthen the connection between educational finance research and the microlevel realities of student development that this volume seeks to foreground.

8. Conclusion

This chapter has examined how a HoloLens 2-supported MR environment shaped academic self-efficacy, academic performance, and SRL within a bounded case of undergraduate civil engineering education. Rather than presenting MR as a neutral teaching aid or a simple performance enhancer, the case has shown that its significance lies in how it alters the conditions under which students inspect their work, interpret feedback, and judge their own capability.

The chapter also highlights the importance of technological readiness. Students did not encounter the immersive environment from identical starting points, and differences in prior AR/VR exposure appeared to shape how readily they could turn MR affordances into strategic learning action. Because socioeconomic status was not directly measured, these differences should not be interpreted as direct evidence of socioeconomic disparity. Rather, they point to a broader equity concern: High-cost educational technologies may require deliberate readiness support if they are to benefit learners with different levels of prior digital experience.

From this perspective, HoloLens 2 and similar MR educational technologies are best understood not merely as instructional tools but as financially enabled learning infrastructures. Their developmental significance lies in how they connect institutional investment with the cultivation of reflective, resilient, and professionally capable learners. For engineering education, the case suggests that immersive technologies may contribute most meaningfully when they are integrated strategically, interpreted pedagogically, and supported as part of a broader commitment to long-term student development.

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Artificial intelligence (AI) tools have not been used in the generation or framing of this work. Limited checking actions relating to language support, including

readability checks, spelling and grammatical correction, were AI-assisted. For these purposes, Microsoft Word's inbuilt tools were used, supplemented by Grammarly (www.grammarly.com/grammar-check).

ChatGPT was used on occasion to assist with initial translation from Mandarin Chinese to English and for language refinement at the sentence and paragraph level without altering the substantive meaning, analytical content, or scholarly interpretation of the work. All intellectual decisions, interpretations, and conclusions remain entirely my own.

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

- [1] Bandura A. Social Foundations of Thought and Action: A Social Cognitive Theory. NJ: Prentice Hall; 1986
- [2] Zimmerman BJ. Becoming a self-regulated learner: An overview. Theory into Practice. 2002;**41**(2):64–70
- [3] Zimmerman BJ. Self-Efficacy: An essential motive to learn. Contemporary Educational Psychology. 2000b;**25**(1):82–91. DOI: 10.1006/ceps.1999.1016
- [4] Yao CW, Bush T, Collins C, Tuliao M, Briscoe KL, Dang NLT. Exploring stem undergraduate self-regulated learning at a Vietnamese transnational university. Journal of Comparative & International Higher Education. 2021;**13**:6–21
- [5] Cieslik VV, Sukhawathanakul P, Rostampour R, Wu MQ, Hadwin AF, Stewart SH, et al. Exploring associations between substance use, self-regulated learning practices, and academic challenges at five Canadian Universities. Journal of College Student Retention Research, Theory & Practice. 2025;**28**:511–533
- [6] Hadwin AF, Sukhawathanakul P, Rostampour R, Bahena-olivares LM. Do self-regulated learning practices and intervention mitigate the impact of academic challenges and COVID-19 distress on academic performance during online learning? Frontiers in Psychology. 2022;**13**:813529
- [7] Zimmerman BJ, Schunk DH, editors. Self-regulated Learning and Academic Achievement: Theoretical Perspectives. New York, NY: Routledge; 2013
- [8] Bandura A. Self-efficacy: The Exercise of Control. NY: Freeman; 1997
- [9] Winne PH. Theorizing and researching levels of processing in self-regulated learning. British Journal of Educational Psychology. 2018;**88**(1):9–20
- [10] Zimmerman BJ. Investigating self-regulation and motivation: Historical background, methodological developments, and future prospects. American Educational Research Journal. 2008;**45**(1):166–183
- [11] Schunk DH, Zimmerman BJ. Social origins of self-regulatory competence. Educational Psychologist. 1997;**32**(4):195–208
- [12] Stake RE. The Art of Case Study Research. Thousand Oaks, CA: SAGE Publications; 1995
- [13] Yin RK. Case Study Research and Applications. Vol. 6. Thousand Oaks, CA: Sage; 2018
- [14] Bandura A. Guide for constructing self-efficacy scales. Self-Efficacy Beliefs of Adolescents. 2006;**5**(1):307–337
- [15] Cleary TJ, Callan GL, Zimmerman BJ. Assessing self-regulation as a cyclical, context-specific phenomenon: Overview and analysis of SRL microanalytic protocols. Education Research International. 2012;**2012**(1):428639. DOI: 10.1155/2012/428639
- [16] Braun V, Clarke V. Thematic Analysis: A Practical Guide. Thousand Oaks, CA: SAGE Publication Ltd; 2022
- [17] Terry G, Hayfield N, Clarke V, Braun V. Thematic analysis. The SAGE Handbook of Qualitative Research in Psychology. 2017;**2**(17-37):25