

Developing and Piloting a Virtual Reality Prototype for Automotive Maintenance Training at a Ugandan Vocational Training Institute: A Design Science Feasibility Study

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Abstract: Vocational training institutes in Uganda often lack tools, vehicles and workshop space for hands-on mechanics training. This study reports the development and feasibility pilot of a virtual reality (VR) training prototype for two automotive maintenance procedures at St Simon Peters Vocational Training Institute in Hoima. The prototype was built for standalone headsets following Design Science Research. Experiential Learning Theory and the Technology Acceptance Model guided requirements and questionnaire items. Thirty participants (25 trainees, 3 instructors and 2 support staff) completed Likert-type and multiple-choice questionnaires. Descriptively, trainees rated VR sessions as more engaging than their usual instruction (mean 4.52 of 5); repeated practice was the benefit most often selected, while ease of use and integration into teaching were rated more moderately. Without a comparison group or performance measure, the study cannot show learning gains. It contributes a described artefact, three provisional design principles and a list of scaling constraints.

Keywords: virtual reality; vocational training; design science research; automotive maintenance; Uganda

INTRODUCTION

Technical and vocational education and training (TVET) is a main route to employment for young people in Uganda, and the 2019 TVET Policy places it within the country's Vision 2040 development agenda (Ministry of Education and Sports [MoES], 2019). Earlier TVET strategies include Skilling Uganda: BTNET Strategic Plan 2011–2020 (MoES, 2012). Implementation remains constrained. The 2019 policy describes delivery as “largely theoretical and academic” and proposes easing access to appropriate training equipment and improving training facilities (MoES, 2019). A critical analysis of the sector reports poor-quality equipment, under-trained staff and weak links with industry (Okumu & Bbaale, 2019), and a recent review lists limited training infrastructure among the factors that reduce TVET effectiveness (Mugaiga & Ocan, 2026).

Automotive mechanics illustrates how these constraints affect practice. At St Simon Peters Vocational Training Institute (VTI) in Hoima, observational reports indicate that trainees rarely handle complete vehicle systems. Tasks such as changing engine oil or replacing brake pads are often demonstrated by instructors using improvised materials, with little direct involvement of trainees. Limited hands-on practice is a plausible threat to workplace readiness, but its extent at the institute was not measured in this study.

Immersive virtual reality (VR) is often proposed for such gaps because it lets learners rehearse a procedure repeatedly and safely, without consuming materials or occupying a vehicle, and it has been linked to higher student engagement in vocational education (Rafiq et al., 2022). The pedagogical case is strongest for procedural knowledge, such as the order of steps, the

identification of parts and safe working practice, where learners can manipulate virtual objects in a controlled sequence. It is weaker for psychomotor skill, because hand controllers do not reproduce the force, torque and tactile feedback of real tools, and haptics that increase realism remain an open research avenue (Radhakrishnan et al., 2021). Reviews likewise indicate that immersive VR suits learning environments that call for active manipulation and practical application (Conrad et al., 2024). Claims that VR is cost-effective or scalable need cost data, which are rarely reported and were not collected in this study.

The evidence base is mixed and should be read with care. Systematic reviews find that evaluations of educational and industrial VR mostly assess usability rather than learning outcomes, that learning theory seldom guides design, and that metrics beyond time and scores are limited (Radianti et al., 2020; Radhakrishnan et al., 2021). Controlled studies are more encouraging for vocational training. A meta-analysis of 53 studies of mixed reality in vocational education and training reported positive effects over control conditions on behavioural, cognitive and affective outcomes ($d = 0.40, 0.84$ and 0.65), although effects were close to zero for behavioural outcomes when two mixed-reality conditions were compared (Bödding et al., 2025). An earlier meta-analysis concluded that extended-reality training is about as effective as conventional training and is most valuable where conventional training is dangerous, costly or impractical (Kaplan et al., 2021). Engagement should not be equated with learning: in a controlled experiment, students using immersive VR reported more presence but showed higher cognitive load and learned less than students using a desktop display (Makransky et al., 2019). This finding underlies the Cognitive Affective Model of Immersive Learning (CAMIL), which proposes that presence and agency support learning only when cognitive load, interest and self-regulation are managed (Makransky & Petersen, 2021).

Evidence on automotive and engine-maintenance training is thinner. A conference study from Malaysia evaluated a VR engine-maintenance model with 67 vocational students and reported task scores, but its abstract describes no comparison group (Lim et al., 2024). In Uganda, a non-systematic search located two relevant precedents: a feasibility study of VR-based training for COVID-19 case handling (Buyego et al., 2022), and a 2017 pilot of 360° “how-to” video clips for TVET trainees, including a motor vehicle repair clip, which cost less than €1,000 and reported no learner outcomes (Enabel, 2017).

Three gaps follow. First, it is unclear how an interactive, step-by-step simulation of automotive procedures can be designed to run on standalone headsets in an institute with shared computer facilities and little prior VR exposure. Second, most educational VR evaluations concentrate on usability rather than learning outcomes, and few draw explicitly on learning theory (Radianti et al., 2020), so the pedagogical rationale for design choices often stays implicit. Third, design studies seldom return explicit design knowledge that others can reuse. A low-resource Ugandan TVET setting adds more than context to these gaps: shared headsets, novice users, instructors with limited VR experience and scarce workshop equipment are design requirements in their own right, and showing how the prototype responded to them is the transferable contribution.

The aim was to design, build and pilot a VR training prototype for two automotive maintenance procedures and to document what the pilot shows about its design and feasibility. Three research questions guided the study.

RQ1. Which instructional requirements and design features should a VR prototype for engine oil change and brake pad replacement include, and how were they implemented?

RQ2. How usable, useful and acceptable do trainees, instructors and support staff find the prototype in a resource-constrained TVET institute?

RQ3. Which constraints and enabling conditions emerged during the pilot, and which provisional design principles follow from them?

The paper contributes (i) a described artefact and its instructional rationale, (ii) descriptive evidence of perceived usability, usefulness and constraints from a single-site pilot, and (iii) three

provisional design principles. It does not test effects on skill acquisition, retention or transfer to real vehicles.

METHOD

Research Design

The study followed the Design Science Research Methodology (DSRM) of [Peffers et al. \(2007\)](#), which specifies six activities: problem identification and motivation, definition of objectives for a solution, design and development, demonstration, evaluation and communication. The broader design-science guidelines of [Hevner et al. \(2004\)](#), which require a purposeful artefact, a relevant problem, rigorous evaluation and clear communication, framed the overall approach. [Table 1](#) shows how each activity was carried out and what evidence it produced.

Table 1. Design Science Research activities, what was done and the resulting evidence

DSRM activity	What was done in this study	Evidence or output
1. Problem identification and motivation	Infrastructure and pedagogical constraints in automotive training at St Simon Peters VTI were identified (see “Background and Problem”).	Policy and sector sources; observational reports
2. Objectives of a solution	Four requirements (R1–R4) were defined.	Requirements list
3. Design and development	Vehicle components were modelled in 3ds Max and the simulation was built in Unreal Engine for two procedures (see “The Artefact: Instructional Design and Development”).	Prototype (Figures 1 and 2)
4. Demonstration	The prototype was installed in the institute’s “Computer Hub” and used by trainees on standalone headsets (see “Implementation of the Pilot”).	Pilot sessions
5. Evaluation	Perceived usability, usefulness, engagement and intention to adopt were assessed with questionnaires (see “Instruments and Data Collection”).	Tables 4 and 5
6. Communication	This paper.	Manuscript

The requirements for the artefact were: R1, simulate the correct sequence and part positioning of the oil-change and brake-pad procedures in a realistic workshop; R2, allow safe, repeatable practice without consumables; R3, give procedural guidance together with the reason for each step; and R4, be operable by novice users on standalone headsets. The original protocol did not set numeric success thresholds, so no cut-off is used to declare success, and the results are interpreted only as indications of feasibility. The study reports a single evaluation of the build in the pilot described in this paper, and no iteration cycles are reported.

Theoretical Lenses

Experiential Learning Theory (ELT; [Kolb, 1984](#)) served as a design lens. It describes learning as a cycle of concrete experience, reflective observation, abstract conceptualisation and active experimentation. [Table 2](#) maps each stage to a prototype feature and the evidence collected, and shows which stages the prototype supports directly.

The Technology Acceptance Model (TAM; [Davis, 1989](#); [Venkatesh & Davis, 2000](#), who extended it as TAM2) guided the choice of questionnaire items on perceived usefulness, perceived ease of use and intention to adopt. TAM was not tested as a model. Each construct is represented by one or two items rather than a validated multi-item scale, so no construct scores, reliability coefficients or predictive relationships are reported. [Table 3](#) shows the link between evaluation criteria and items.

Table 2. Mapping of the ELT stages to design requirements, prototype features and evidence

ELT stage	Design requirement	Prototype feature	Evidence in this study	Status
Concrete experience	Realistic simulation that mirrors real-world scenarios	Virtual garage with 3D vehicle and tool models; trainee performs steps with hand controllers	Q14; Q16 (realistic 3D models and simulation: 13 of 37)	Implemented
Reflective observation	Feedback loops that prompt trainees to evaluate their actions and outcomes	Step-by-step guidance; the design intends each step to be completed before the next begins	Q16 (immediate feedback and guidance: 7 of 37)	Partly implemented
Abstract conceptualisation	Clear instructions and theory inside the system that explain why each step is done	Voice guidance that explains what to do and why	None collected	Partly implemented
Active experimentation	Let learners apply and repeat the procedure	Repeatable tasks	Q16 (practise tasks multiple times: 23 of 37)	Implemented

Counts are respondents who selected the option out of all respondents to Q16 (Table 5).

Table 3. Evaluation criteria, questionnaire items and respondents

Evaluation criterion (TAM proxy)	Items	Respondents
Perceived usefulness (proxy)	Q10 (belief that VR can improve practical skills), Q13 (confidence), Q14 (understanding of components), Q21 (instructional benefits; multiple choice)	Trainee questionnaire (Q10, Q13, Q14); instructor/trainer questionnaire (Q21)
Perceived ease of use (proxy)	Q15 (instructions and controls), Q19 (integration into teaching)	Trainee questionnaire (Q15); instructor/trainer questionnaire (Q19)
Engagement	Q12 (compared with traditional methods), Q20 (observed student engagement)	Trainee questionnaire (Q12); instructor/trainer questionnaire (Q20)
Intention to adopt or scale (proxy)	Q25	Institutional and adoption questionnaire (Q25)
Context and expectations	Q8 (challenges), Q9 (VR familiarity), Q11 (expectations), Q16 (most beneficial aspect)	Trainees
Constraints and enabling conditions	Challenges identified during the pilot (not quantified; see “Relation to Previous Research”)	Not applicable

The Artefact: Instructional Design and Development

The prototype guides a trainee through two procedures. In the engine oil change the trainee uses the recommended tools in a virtual modern garage to lift the vehicle, open the oil sump drain, remove the oil filter and refill with new oil. In the brake pad replacement the trainee removes the wheel, removes the worn pads and fits new ones.

Each procedure is accompanied by voice guidance that explains what to do and why. A guidance layer was added to ease the flow of instruction and to check each step before the next one begins; how well it works was not evaluated in this study. Interaction uses the headset’s hand controllers. Fidelity was concentrated on the visual realism of components and layout, and tactile fidelity was not attempted. Controller interaction cannot build the manual dexterity needed with

real tools, so the prototype is intended to support procedural knowledge and rehearsal, not to replace work on real vehicles.

Vehicle components, including engine blocks, gears and workshop tools, were modelled in 3ds Max (Autodesk, 2023). Unreal Engine (Epic Games, n.d.) provided the real-time platform on which the 3D assets were assembled into interactive tasks, using Blueprints and C++ scripting. Figures 1 and 2 show the development environments and the start screen of the brake pad replacement module.

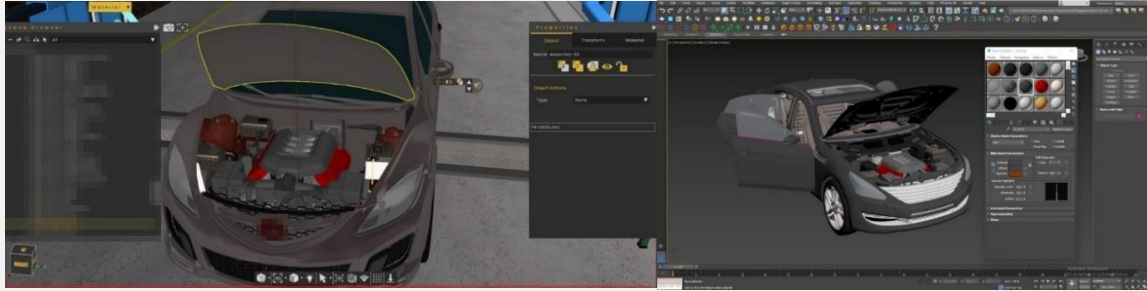


Figure 1. Development environments of the prototype. (a) Simulation design in Unreal Engine, (b) 3D modelling of vehicle components in 3ds Max.



Figure 2. Start screen of the brake pad replacement module.

Setting and Participants

The pilot took place at St Simon Peters VTI in Hoima, western Uganda. Thirty participants were purposively selected: 25 trainees, 3 instructors and 2 support staff. Trainees were eligible if they were enrolled in the automotive department and had used the VR platform. Purposive sampling was chosen because the evaluation needed views from people with direct experience of motor vehicle training and of the prototype. It limits generalisation (see “Limitations”).

Implementation of the Pilot

The prototype was installed in the institute’s “Computer Hub” and run on Meta Quest headsets. The number of headsets, the length and number of sessions, the rotation of participants and the costs are not reported, which limits replication (see “Limitations”).

Instruments and Data Collection

Data were collected with four questionnaire sections: (A) a pre-training baseline questionnaire for trainees, (B) a post-training questionnaire for trainees, (C) instructor and trainer feedback, and (D) institutional and adoption feedback. Items were numbered Q1 to Q25, and the items analysed here are listed in Tables 4 and 5. Most items were rated on a five-point Likert-type scale. Four items (Q8, Q11, Q16 and Q21) were multiple choice. Q25 (“Do you think VR training should be scaled to other vocational institutions in Uganda?”) is worded as a yes/no question but was summarised on a five-point scale, so it is interpreted cautiously (see “Perceived Usability, Usefulness and Engagement”).

The questionnaires were reviewed by two subject experts. This was an expert review and not a formal content-validity procedure: no content validity index is reported. This paper reports the questionnaire data only.

Data Analysis

Likert-type responses are ordinal, so means and standard deviations are used only as descriptive summaries (Sullivan & Artino, 2013). Medians, response distributions and item-level numbers of respondents are not reported for the Likert-type items. No inferential tests were run. The pre-training items (Q9 and Q10) measure baseline familiarity and expectations and are not paired with post-training items, so no pre/post comparison is made or claimed. Internal consistency is not reported because the items measure different constructs, were answered by different respondent groups, and each construct has only one or two items.

RESULTS & DISCUSSION

The Prototype

The prototype implements both procedures with voice guidance and requires parts to be positioned correctly (see “The Artefact: Instructional Design and Development”; Figures 1 and 2).

Participants and Response Counts

Thirty participants were recruited (25 trainees, 3 instructors and 2 support staff). The survey export recorded 39, 39, 37 and 27 responses to the four multiple-choice items (Table 5), which exceed the 30 recruited participants. The available summary does not explain this discrepancy, so the item-level counts are reported as recorded and are interpreted with caution. The means for the two items in the instructor/trainer section (Q19 and Q20) are not arithmetically possible with only three respondents, so the number and identity of respondents to that section are uncertain.

Perceived Usability, Usefulness and Engagement

Among trainees, the highest-rated item was engagement relative to usual instruction (Q12: $M = 4.52$, $SD = 1.00$), followed by perceived understanding of components (Q14: $M = 4.19$, $SD = 1.39$), confidence in performing tasks (Q13: $M = 4.07$, $SD = 1.36$) and the prior belief that VR can improve practical skills (Q10: $M = 3.96$, $SD = 1.40$). Ease of use of instructions and controls was rated lower (Q15: $M = 3.74$, $SD = 0.98$). Baseline familiarity with VR was moderate and varied widely (Q9: $M = 3.59$, $SD = 1.45$), which suggests that some trainees already knew VR while others did not. The two items in the instructor/trainer section had moderate means: perceived increase in student engagement (Q20: $M = 3.71$, $SD = 0.46$) and ease of integration into teaching (Q19: $M = 3.32$, $SD = 0.99$). The item on scaling VR to other institutions had the highest mean (Q25: $M = 4.93$, $SD = 0.38$); because it is worded as a yes/no question, it is best read as strong stated support rather than as a measure on a graded scale.

These are perceptions. They do not show learning or performance, and standard deviations of about 1.0 to 1.5 on a five-point scale indicate considerable disagreement among trainees on several items. Item-level n is not available (see “Participants and Response Counts”), so differences between respondent groups are not interpreted.

Table 4. Item wording and descriptive statistics for the Likert-type items

Section	Item	Item text	Mean	SD
A. Pre-training (trainees)	Q9	How familiar are you with Virtual Reality (VR) technology?	3.59	1.45
	Q10	I believe VR-based training can improve practical mechanical skills	3.96	1.40
B. Post-training (trainees)	Q12	How engaging was the VR training compared to traditional methods?	4.52	1.00
	Q13	I feel more confident in performing mechanical tasks after using the VR platform	4.07	1.36
	Q14	The VR platform helped me understand car components better than textbooks or lectures	4.19	1.39
	Q15	Were the instructions and controls in the VR simulation easy to use?	3.74	0.98
C. Instructor / trainer feedback	Q19	The VR training platform was easy to integrate into my teaching	3.32	0.99
	Q20	I observed increased student engagement while using VR	3.71	0.46
D. Institutional / adoption feedback	Q25	Do you think VR training should be scaled to other vocational institutions in Uganda?	4.93	0.38

Means and SDs are as reported in the original submission; item-level numbers of respondents are not available (see "Participants and Response Counts"). Responses on a five-point scale.

Challenges, Expectations and Perceived Benefits

Table 5. Responses to the multiple-choice items

Option	n	%
<i>Q8. Biggest challenge in accessing practical training (trainee questionnaire; 39 responses)</i>		
Limited access to real vehicles	14	35.9
Inadequate tools or equipment	11	28.2
Lack of time for hands-on practice	9	23.1
Overcrowded workshops	4	10.3
Engine overhauling	1	2.6
<i>Q11. Expectations of the VR training (trainee questionnaire; 39 responses; multiple selections)</i>		
To improve hands-on mechanic[al skills]†	19	48.7
To better understand how vehic[le systems work]†	14	35.9
To practice safely without dama[ging equipment]†	11	28.2
To prepare for real-life job tasks	10	25.6
To reduce the need for physical [resources]†	9	23.1
To make learning more interactive†	7	17.9
Improve my practical mechanic[al skills]†	1	2.6
<i>Q16. Most beneficial or enjoyable aspect (37 responses; multiple selections)</i>		
Ability to practice tasks multiple [times]†	23	62.2
Realistic 3D models and simula[tion]†	13	35.1
Immediate feedback and guid[ance]†	7	18.9
Interactive and immersive enviro[nment]†	6	16.2
Easy-to-use interface and contr[ols]†	6	16.2
Gamified elements (challenges...)†	2	5.4
Everything	1	2.7
Other / unlabelled response	1	2.7
<i>Q21. Instructional benefits gained (27 responses; multiple selections)</i>		
More effective demonstration of mechanical concepts	18	66.7
Enhanced ability to explain complex tasks step-by-step	10	37.0
Increased student engagement during lessons	9	33.3
Flexibility in lesson planning and teaching pace	4	14.8
Easier tracking of student progress and performance	3	11.1
Other / unlabelled response	1	3.7

Counts and percentages are taken from the survey export; percentages are of respondents to the item. Q8 was set up as “select all that apply”, but its 39 selections equal its 39 responses, so each respondent’s answer appears to have been recorded once. †Option wording is truncated in the survey export; bracketed text is a reconstruction of the likely wording.

Asked about their biggest challenge in accessing practical training (Q8), respondents most often chose limited access to real vehicles (14 of 39; 35.9%) and inadequate tools or equipment (11; 28.2%), followed by lack of time for hands-on practice (9; 23.1%) and overcrowded workshops (4; 10.3%). Their main expectations of VR (Q11) were to improve hands-on mechanical skills (19 of 39; 48.7%) and to better understand how vehicle systems work (14; 35.9%). Of 37 respondents to Q16, 23 (62.2%) named the ability to practise tasks multiple times as the most beneficial or enjoyable aspect and 13 (35.1%) named realistic 3D models and simulation. Q21, on instructional benefits, had 27 responses: 18 (66.7%) chose more effective demonstration of mechanical concepts, 10 (37.0%) an enhanced ability to explain complex tasks step by step and 9 (33.3%) increased student engagement during lessons.

Discussion

Principal Findings

In this single-site pilot, the prototype was built with commercial tools, installed in an institute computer room and used by trainees and staff for two automotive procedures. Respondents rated it favourably on engagement, understanding of components and intention to scale, and the benefit most often selected was repeatable practice. Ease of use for trainees and ease of integration for instructors were rated more moderately. Because there was no comparison group, no performance measure and no pre/post comparison, the data speak to feasibility and perceived usefulness and not to learning gains, transfer to real vehicles or cost-effectiveness.

Relation to Previous Research

The emphasis on perceptions is typical of the field: reviews find that evaluations of educational and industrial VR mostly assess usability and rely on few learning-theory-based designs and on metrics limited to time and scores (Radianti et al., 2020; Radhakrishnan et al., 2021). The present study adds a Ugandan TVET case of this type and shares its limitation. Meta-analytic evidence from controlled studies reports positive effects of mixed reality on behavioural, cognitive and affective outcomes in vocational education (Bödding et al., 2025), and extended reality (XR) training has been found to be as effective as conventional training, with particular value where conventional training is costly, dangerous or impractical (Kaplan et al., 2021). The second conclusion fits the rationale of this study: when asked about their biggest challenge in accessing practical training, 25 of 39 respondents chose limited access to real vehicles or inadequate tools or equipment (Q8). Our data cannot test whether the prototype delivers the outcomes reported in those meta-analyses.

The engagement ratings should not be read as learning. In a controlled comparison, immersive VR raised presence but increased cognitive load and reduced learning relative to a desktop version (Makransky et al., 2019), and the CAMIL holds that presence and agency support learning only when cognitive load, interest and self-regulation are managed (Makransky & Petersen, 2021). We did not measure cognitive load, presence or learning, so we cannot say where the prototype falls on that spectrum.

Compared with the Malaysian engine-maintenance study (Lim et al., 2024), which reported task scores without a comparison group in its abstract, our pilot describes an interactive module with explicit design intentions and includes instructors’ views, but it has no performance data. Compared with the 360° video clips piloted in Uganda in 2017 (Enabel, 2017), the prototype lets trainees act on the virtual vehicle, although we have no evidence that this interactivity improves learning. Buyego et al. (2022) also examined the feasibility of VR-based training in Uganda, in a health-care context, and a comparison of constraints across the two settings would be informative.

Constraints identified during the pilot included limited availability of headsets, short interaction times and occasional reluctance among staff unfamiliar with immersive technology;

these were not quantified in this study. Claims about cost and sustainability could not be tested because cost data were not collected; they remain hypotheses.

Provisional Design Principles

We offer three design principles as provisional propositions, not validated findings. Each follows from a design decision, is linked to literature, and is supported in this study only by perceptions (Table 6).

Table 6. Provisional design principles for VR in resource-constrained vocational training

Principle	Rationale	Evidence in this study	How it could be tested
DP1. Gate each step and allow unlimited repetition. Structure procedures as ordered, checkable steps and allow repeated attempts without consumables.	Procedural tasks suit active manipulation (Conrad et al., 2024); repetition is a core affordance of VR training.	23 of 37 respondents (62.2%) chose repeated practice as the most beneficial aspect (Q16); trainees rated engagement relative to usual instruction highest (Q12: $M = 4.52$).	Compare error rates and completion time with and without step gating.
DP2. Concentrate fidelity where it supports the procedure. Prioritise realistic components, tools and layout; accept low tactile fidelity; omit non-essential scene detail.	Representational fidelity and cognitive load are central in the CAMIL (Makransky & Petersen, 2021); immersion can overload learners (Makransky et al., 2019).	13 of 37 (35.1%) chose realistic 3D models and simulation (Q16); perceived understanding of components Q14: $M = 4.19$.	Compare scene variants with different detail, measuring cognitive load and knowledge.
DP3. Pair the headset with a facilitator-led orientation and debrief, and plan for shared headsets. Use short modular tasks, observer roles and a debrief that supplies the reflection and conceptualisation that voice guidance alone cannot.	ELT stages; reflective tasks are associated with better outcomes in immersive learning (Lui et al., 2023).	Moderate ease-of-use rating (Q15: $M = 3.74$) and widely varying baseline familiarity (Q9: $SD = 1.45$); limited headsets and short interaction times identified during the pilot; reflective stages not evidenced (Table 2).	Compare sessions with and without structured debrief, and different headset-rotation designs.

Reading ELT and TAM

Table 2 shows that the prototype directly supports concrete experience and active experimentation. Reflective observation and abstract conceptualisation are only partly supported: voice guidance that explains each step does not by itself require learners to reflect or conceptualise, and we collected no evidence that trainees moved through the four stages of the cycle. We therefore do not claim that the study aligns with ELT beyond its role in shaping the requirements. A facilitator-led debrief, or in-VR prompts such as asking trainees to predict the next step or explain an error, would be needed to close the cycle.

TAM supplied the logic for item selection only. The items are single-item proxies for usefulness, ease of use and intention, no model was estimated, and favourable ratings are not evidence that perceived usefulness or ease of use predicted acceptance. Testing acceptance would require a validated multi-item TAM instrument, ideally with VR-specific factors such as presence and cybersickness.

Equity, Accessibility and Scalability

Several equity issues bear on any scaling recommendation and were not assessed. Gender: the gender distribution was not reported, so possible differences in ratings could not be examined.

Accessibility: interaction that requires standing and raising the arms may exclude trainees with motor or visual impairments, and headset fit varies. **Prior digital skills:** baseline familiarity varied widely (Q9: $SD = 1.45$). **Infrastructure:** standalone headsets reduce dependence on connectivity but still need charging, secure storage and maintenance. **Cost:** every additional institute would need headsets, charging, maintenance and instructor time, and no costs were collected in this study. Until these are examined, the strong stated support for scaling (Q25: $M = 4.93$) is an expression of intent and not evidence that scaling is feasible or equitable.

Limitations

The study has a single site, a small purposive sample (30 participants), and perceptions as its only outcome. Self-reports may be affected by novelty and social desirability, particularly because trainees were rating a new technology introduced by their institute. The paper does not report who administered the questionnaires, participants' age, gender or prior VR experience, or implementation details such as the number of headsets and the length of sessions, which limits replication. There was no comparison group, no performance or transfer measure and no follow-up, and exposure was short. The instruments were expert-reviewed but not formally validated, the constructs are single-item proxies, and the item-level response counts exceed the number of recruited participants (see "Participants and Response Counts"). Findings should therefore be read as evidence of feasibility and as a basis for hypotheses, not as evidence of effectiveness.

CONCLUSION

This study designed, built and piloted a VR prototype for two automotive maintenance procedures at a Ugandan vocational training institute. The pilot shows that such a prototype can be developed with commercial tools and run on standalone headsets in an institute computer room, and respondents viewed it favourably: trainees rated it more engaging than their usual instruction, and the benefit most often selected was repeatable practice. The data do not show that the prototype improved skills, and the study should be read as a development-and-feasibility study.

Implications for instructors. The prototype is best used as a complement to, not a replacement for, work on real vehicles, with a facilitator-led orientation and debrief (DP3) and short modular tasks where headsets are shared. **For institutions.** Plans to adopt VR should budget for headsets, charging, maintenance and instructor time, and should define the number of headsets per trainee in advance. **For policy makers.** The findings support funding controlled pilots with performance outcomes in TVET institutions. They do not, on their own, support national curriculum integration. **For developers.** The provisional principles in [Table 6](#) can be tested and refined in other trades and settings.

Next studies. (1) A controlled or quasi-experimental study comparing VR plus usual instruction with usual instruction alone, using performance checklists scored by assessors blind to condition and a transfer test on a real vehicle. (2) Validated measures of usability, technology acceptance, presence, cognitive load and cybersickness. (3) Delayed post-tests of retention. (4) A cost analysis per trainee. (5) Multi-site replication with attention to gender, disability and prior digital skills. (6) Tests of design principles DP1 to DP3 using design variants.

DECLARATIONS

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Data Availability Statement: Aggregated results are reported in [Tables 4](#) and [5](#). No dataset has been deposited in a public repository.

Declaration of AI Use: The authors did not use generative AI or AI-assisted tools in the preparation of this manuscript.

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