Augmented Reality Green Training: Elevating Environmental Knowledge and Driving Pro-Environmental Behaviour Among Indonesian White-Collar Workers

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Abstract. This study is conducted to analyse the impact of AR Green Training in enhancing environmental knowledge and further indulging in the creation of pro-environmental behaviour among white-collar workers working in Indonesia. Results from this quantitative research design distinctly engaged participants from Greater Jakarta with an augmented reality-enhanced training program, analysing data with structural equation modelling. The results show that augmented reality green training improves their knowledge about the environment significantly, and that very factor, in turn, catalyses pro-environmental behaviour. This confirms the hypothesis that environmental knowledge mediates AR training and pro-environmental behaviour. These findings underline, therefore, the utility of AR as a very strong educational tool for corporate sustainability initiatives in increasing knowledge and changing real behaviour towards environmental stewardship. The value that the study adds to the literature is that it demonstrates the effectiveness of immersive technologies in environmental education and strengthens the theoretical underpinning for TPB within a new context. The implications suggest that businesses can enhance their sustainability efforts by integrating AR into their training programs, which may significantly impact the environment. It is thus a call for further research in the sphere of long-term behavioural change and integration of new technologies in environmental training.

1 Introduction

The growing focus on environmental sustainability underscores the importance of education and training in shaping pro-environmental behaviour (PEB). For instance, augmented Reality (AR) systems enhance skill acquisition and performance in various domains, such as surgical training and industrial contexts. In surgical training, AR displays

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instructional information at critical moments, improving skill acquisition [1]. Similarly, in industrial settings, AR training systems allow users to practice on expensive equipment safely, thereby enhancing operational skills while reducing training costs [2].

AR and Virtual Reality (VR) technologies create immersive learning environments that significantly improve construction engineering and woodworking outcomes. These technologies, collectively known as Extended Reality (XR), provide risk-free training scenarios that promote best practices and skills development [3]–[5]. They support sectors by offering cost-effective training solutions through the use of affordable smart devices and webcams, which facilitate virtual training support and time efficiency improvements in tasks like parts assembly [2], [6].

Moreover, XR technologies contribute to the digital and green transformation of vocational education and training. By focusing on sustainability and circular economy practices, XR immersive scenarios help prepare learners for environmentally responsible practices in their respective fields [4].

AR applications are designed with interactive and intuitive interfaces, enabling users to interact with real-world elements through mobile devices. This approach aids in understanding complex systems, such as mobile manipulator robots, by simulating control algorithms and providing visual animations [1], [7]. Additionally, AR and VR technologies create immersive learning experiences in fields like neurosurgery, where trainees can participate virtually in surgical procedures, gaining insights and knowledge without physical presence [3], [8]. AR technologies enhance knowledge acquisition across various disciplines by offering interactive and engaging training content. They prove effective in educating users about intricate systems and procedures, fostering skill development and preparing individuals for real-world challenges in environmentally conscious ways.

2 Literature Review

2.1 The Theory of Planned Behaviour (TPB)

The Theory of Planned Behaviour (TPB), developed by Ajzen in 1985, is a psychological framework that elucidates human behaviour through three key determinants: attitudes, subjective norms, and perceived behavioural control. In the realm of pro-environmental behaviour, TPB has been extensively utilised to predict and promote actions beneficial to the environment.

Attitudes, subjective norms, and perceived behavioural control consistently emerge as significant predictors of pro-environmental intentions and behaviours across numerous studies [9]–[14]. Positive pro-environmental attitudes and a strong sense of perceived control over behaviour are particularly influential in fostering intentions and actions that benefit the environment [10], [12]–[14].

Extended models of TPB, incorporating factors such as moral norms, environmental identity, and empathic concern, enhance the predictive capacity of the framework in explaining pro-environmental intentions [12], [14]–[16]. Additionally, environmental ethics and emotional intelligence play pivotal roles in shaping pro-environmental behaviours, especially within organisational contexts [14], [16].

TPB's applicability extends across various pro-environmental behaviours, encompassing areas such as waste management, green consumption, energy conservation, and sustainable transportation [9]. Tailored interventions based on TPB have been studied among diverse demographic groups, including high-school students and university employees, to promote pro-environmental actions effectively [12]–[14], [16].

Methodologically, researchers stress the importance of accurately measuring and reporting the variance explained by TPB constructs to strengthen its application in predicting behaviour (reference 3). Recommendations include expanding the original TPB

model and integrating additional variables to capture the complexities inherent in pro-environmental behaviours [15], [17], [18].

2.2 Augmented Reality (AR) in Green Training

Augmented Reality (AR) has emerged as a transformative tool for enhancing training across diverse medical, industry, and education sectors. Integrating AR into training programs, particularly in green training contexts, offers immersive and interactive learning experiences that enhance knowledge retention and skill acquisition.

AR technologies create engaging and interactive learning environments capable of simulating real-life scenarios and providing authentic learning tasks [19], [20]. By overlaying virtual objects onto the real world, AR enhances the realism and immersion of training environments, facilitating effective training systems [21], [22].

Combining AR with intelligent tutoring systems allows for personalised feedback and support, adapting training to individual learner needs and improving overall training outcomes [21]. AR proves particularly effective for procedural training tasks, providing scalable interaction concepts and didactic frameworks that enhance the learning of complex procedures [23]. Hybrid AR simulators, integrating real and virtual components, have demonstrated effectiveness in surgical training by offering accurate visualisation and real-time tracking of anatomical structures [22].

Successful implementation of AR in training requires careful consideration of task assessment, selection of appropriate AR tools, and practical implementation strategies [24]. Designing effective AR training systems involves focusing on explicitness, redundant feedback mechanisms, and effective onboarding processes to ensure user engagement and optimise learning effectiveness [23].

2.3 The Influence of AR Green Training on Environmental Knowledge

Recent research has focused on the impact of Augmented Reality (AR) Green Training on environmental knowledge, synthesising findings to understand its effects on related outcomes. Green training enhances green environmental performance significantly by improving competencies related to skills, abilities, knowledge, behaviour, attitude, and awareness [25]. It positively influences knowledge acquisition, which plays a crucial role in fostering both exploitative and exploratory green innovations [26], [27].

Training aimed at developing green abilities also increases environmental awareness among employees, a fundamental aspect of promoting environmental sustainability [28]. Moreover, there is a notable positive relationship between the green knowledge gained from training and employees' commitment to environmental sustainability [28].

Green training acts as a mediator between top management support and green procurement by enhancing awareness, responsibility, technical knowledge, and skills [29]. It emerges as the most effective green human resource management practice in predicting individual environmental performance, particularly in environments with perceived organisational support for environmental initiatives [30]. Therefore, the proposed research hypothesis is as follows:

H1 : *AR Green Training has a significant influence on environmental knowledge.*

2.4 The Influence of Environmental Knowledge on Pro-Environmental Behaviour

The relationship between environmental knowledge and pro-environmental behaviour is

a pivotal area of research, particularly in addressing global environmental challenges. Understanding how knowledge influences behaviour is crucial for designing effective educational and policy interventions to promote sustainable practices. Whether objective or subjective, environmental knowledge significantly impacts pro-environmental behaviour, although it is not the sole determinant [31]–[34]. Action-related environmental knowledge directly influences behaviour in private spheres, while ecological worldviews shape behaviour in public spheres [32].

Motivation and perceived effectiveness play critical roles in explaining pro-environmental behaviour, often exerting more influence than knowledge alone [31]. The complexity of factors influencing pro-environmental behaviour includes personal and social elements such as values, attitudes, cultural influences, and environmental structures [35]–[37].

Effective environmental education should impart both human-environment system knowledge and environmental action knowledge to foster pro-environmental behaviour [33] (). Educating individuals about local and global environmental issues and their behavioural impacts is essential for cultivating environmental citizenship [32].

Attitudes and green trust mediate the relationship between environmental knowledge and pro-environmental behaviour, underscoring that knowledge alone may not suffice [38]. Environmental knowledge can also intricately moderate the relationship between prosocial values and environmental attitudes, indicating a nuanced interplay between knowledge and values [36].

While empathy correlates positively with pro-environmental attitudes and behaviour, environmental knowledge emerges as a stronger predictor, challenging the assumption that fostering empathy alone can drive sustainable behaviour [34]. Hence, the research hypothesis proposed is:

H2: *Environmental knowledge has a significant influence on pro-environmental behaviour.*

2.5 The Influence of AR Green Training on Pro-Environmental Behaviour through Environmental Knowledge as the Mediator

The relationship between environmental training, environmental knowledge, and pro-environmental behaviour has garnered extensive research attention. Understanding whether environmental knowledge mediates this relationship is crucial for developing effective interventions to promote sustainable behaviours.

Environmental training significantly increases the likelihood of pro-environmental behaviours, such as recycling and participating in environmental events [39], [40]. It particularly enhances voluntary pro-environmental behaviours compared to other types of behaviours [39].

Environmental knowledge plays a pivotal role as a mediator in promoting pro-environmental behaviour, indicating its positive influence [41]–[43]. Moreover, knowledge sharing further amplifies the impact of environmental knowledge on pro-environmental behaviour [43].

Several factors moderate the relationship between environmental knowledge and pro-environmental behaviour. Environmental attitudes and behavioural intentions mediate this relationship, emphasising their role in shaping behaviours [44]. Additionally, green self-efficacy and green rewards mediate the link between environmental leadership and pro-environmental behaviour, with training acting as a moderator [40].

Perceptions of the environment also partially mediate the relationship between

environmental knowledge and pro-environmental behaviour [41]. Furthermore, environmental knowledge moderates the influence of prosocial values and environmental attitudes on behaviour, highlighting its role in shaping behavioural outcomes [36].

Both general and specific environmental knowledge are crucial antecedents of pro-environmental behaviour, with general knowledge demonstrating a robust association with environmental behaviours [42]. Knowledge about environmental and eco-labels, alongside green trust, significantly correlates with pro-environmental behaviour, mediated by attitudes and trust [38]. Environmental knowledge acts as a mediator in the relationship between environmental training and pro-environmental behaviour. Training enhances knowledge, which in turn influences behaviour. This relationship is further moderated by factors such as environmental attitudes, values, and perceptions. Effective interventions should enhance environmental knowledge through training and foster positive environmental attitudes and values to promote sustainable behaviours. Therefore, the proposed research hypothesis as follows:

H3: *AR Green Training significantly influences pro-environmental behaviour through environmental knowledge as the mediator.*

3 Research Methodology

3.1 Research Design and Approaches

This research involved a cross-sectional survey with a quantitative approach using partial least square structural equation modeling (PLS-SEM) to justify the conceptual framework and proposed hypothesis. The study was conducted in Greater Jakarta, which was selected because Jakarta is the capital city of Indonesia surrounded by satellite cities. Additionally, the research model presented in this paper is depicted in Figure 1. The model is derived from preliminary papers and relevant underpinning theories.

Fig. 1. Research Framework

3.2 Data Collection

The researchers conducted a study involving 200 employees in Greater Jakarta using convenience sampling due to the absence of a sampling frame. This method facilitated quick data collection, with efforts made to minimise associated biases. Data were collected using online questionnaires distributed via Google Forms through email and WhatsApp, and participation was voluntary. Initially, 250 questionnaires were sent out, and 235 responses were received. Of these, 35 incomplete ones were excluded. Rasch Model Analysis was employed to detect and remove outliers, specifically using Person Measure Analysis to evaluate response bias. Based on established criteria, 35 outliers were eliminated because their MNSQ value fell between 0.5 and 1.5 [45], [46].

3.3 Research Instrument

The research instrument was developed based on scholarly literature, with the questionnaire items adapted from the work of [47], [48]. The research items are presented in Table 1.

Table 1. Research Instrument

Instrument Penelitian	
Item	**AR Green Training (AGT)**
AGT1	Interactive modules in workspaces for environmental awareness featuring quizzes and videos.
AGT2	AR checklist or flowchart for training sessions emphasising environmental considerations.
AGT3	Virtual bookshelves and digital libraries are accessible via AR interfaces.
AGT4	AR indicators on training schedules for environmental priorities.
AGT5	Skill trackers and virtual mentors in AR for environmental training.
AGT6	Real-time tips in AR during activities like travel planning and recycling.
AGT7	AR posters and campaigns in common areas for environmental messages.
AGT8	Virtual classrooms and educational modules are accessible through AR.
AGT9	AR overlays for real-time workspace environmental impact analysis.
AGT10	Rotational training plans and progress trackers using AR.
AGT11	AR survey tools and dashboards for identifying training needs.
AGT12	AR bulletin boards and notifications for training opportunities.
Item	**Environmental Knowledge (EK)**
EK1	I know about the problem of environmental pollution caused by chemicals.
EK2	I have a good knowledge of environmental issues.
EK3	I can see with my own eyes that the environment is deteriorating.
EK4	I am aware of how to protect the environment from pollution.
EK5	I am aware about climate change.
EK6	I know what clean energy is and how to promote it.
EK7	I have knowledge of landfill waste and its hazards.
EK8	I am aware about unsustainable consumption.
EK9	I know about land degradation and ways to stop it.
Item	**Pro-Environmental Behaviour (PEB)**
PEB1	I actively propose environmentally friendly practices to improve our organisation's environmental performance.
PEB2	I participate in environmentally friendly programs at work.
PEB3	I share my environmental knowledge with colleagues.
PEB4	I suggest new practices to enhance our organisation's environmental performance.
PEB5	I question practices at work that could harm the environment.
PEB6	I consider the environmental impact of my actions before proceeding.
PEB7	I voluntarily undertake environmental tasks beyond my job requirements.
PEB8	I conserve resources like electricity and water at work.
PEB9	I opt for stairs over elevators at work to save energy.
PEB10	I turn off lights when leaving rooms at work.
PEB11	I print double-sided whenever feasible.
PEB12	I recycle materials such as paper, cans, batteries, and oil at work.
PEB13	I perform my assigned duties in environmentally friendly ways.
PEB14	I fulfil my job responsibilities in environmentally sustainable ways.
PEB15	I complete tasks expected of me in environmentally responsible ways.
PEB16	Compared to my colleagues, I minimise waste and promote recycling at work.

Source: Authors, 2023

3.4 Data Analysis

The chosen data analysis method is structural equation modeling (SEM). This approach enables researchers to test models that capture the hierarchical structure of constructs, offering a nuanced understanding of the relationships among observed and latent variables [49], [50]The analysis will be performed using SMARTPLS 3.2.9 software. The aim is to deepen our comprehension of relationships between observed and latent variables, thereby contributing to a comprehensive understanding of the research model.

3.5 Common Method Variance Estimation

To address common method bias, the Rasch Model Analysis is recommended as an effective strategy for reducing biased responses in self-report questionnaires [45], [46]. Person Measure Analysis is specifically utilised to assess potential response biases, with the ideal MNSQ value falling between 0.5 and 1.5 [45], [46]. Data collected underwent Rasch Model analysis using WINSTEPS 5.2.1.0 software.

4 Results and Discussion

This national-scale study did not focus on any particular region in Indonesia. However, most respondents were sourced from Java Island, reflecting the high concentration of white-collar employees there. This trend is attributed to Jakarta, the capital city of Indonesia, being located on Java Island. The research spanned from June 2023 to December 2023.

4.1 Demographics of Respondents

The study surveyed 200 respondents from various companies in Greater Jakarta, Indonesia. The majority were aged 21-30 (46.5%) and 31-40 (39.5%). Male respondents comprised 59%, while females accounted for 41%. Most had less than five years of work experience (51%), followed by less than ten years (37.5%) and less than 20 years (10%). Regarding education, 63.5% held a bachelor's degree, 10% had high school/vocational education, 10% had a Diploma 1-4, and 16.5% had a master's degree or higher. Regarding employment, 35% worked in national private companies, 20% in government institutions, 16.5% in state-owned companies, 13.5% in entrepreneurial businesses, and 6% in international companies.

4.2 Measurement Model Analysis

Validity and reliability (Table 2) in this study were evaluated using SmartPLS 3.2.9 software. Convergent validity was assessed by ensuring that indicators had outer loadings exceeding 0.7, aligning with guidelines from [49], [50]. Variables were deemed valid if their Average Variance Extracted (AVE) exceeded 0.5.

Table 2. Measurement Model Analysis

Items	Loading Factor (>0.7)	Cronbach's Alpha (>0.6)	Composite Reliability (>0.6)	AVE (>0.5)	Remarks
GT1	0.785	0.854	0.889	0.534	Valid and Reliable
GT10	0.742				
GT11	0.725				
GT3	0.732				
GT5	0.727				
GT6	0.704				
GT7	0.696				
EK1	0.774	0.811	0.864	0.515	Valid and Reliable
EK3	0.719				
EK4	0.720				
EK5	0.734				
EK7	0.665				
EK9	0.690				
PB14	0.752	0.783	0.852	0.535	Valid and Reliable
PB15	0.749				
PB3	0.685				

Items	Loading Factor (>0.7)	Cronbach's Alpha (>0.6)	Composite Reliability (>0.6)	AVE (>0.5)	Remarks
PB4	0.713				
PB8	0.755				

Source: Authors, 2023
Notes: GT: AR Green Training; EK: Environmental Training; PEB: Pro-Environmental Behaviour

Reliability in this study was evaluated using guidelines from [49], [50], with composite reliability values exceeding 0.6 considered reliable. Similarly, Cronbach's alpha values above 0.6 indicate reliability. Table 2 confirms the validity of indicators with loading factor values exceeding 0.7, and AVE values for each variable surpassing 0.5 further support their validity. Additionally, all variables demonstrate composite reliability values exceeding 0.6, indicating overall reliability and validity across the board.

4.3 Structural Model Analysis

According to [49], [50] R-Square values above 0.75 indicate high influence, values around 0.5 signify moderate influence, and values around 0.25 suggest low influence. Table 3 shows Environmental Knowledge with R-Square 0.651. It indicates that the model for environmental knowledge can explain approximately 65.1% of the variance in the dependent variable. This is a substantial proportion, suggesting that the model has a relatively good fit for this variable.

Table 3. R-Square Analysis

Variable	R-Square
Environmental Knowledge	0.651
Pro-Environmental Behaviour	0.654

Source: Authors, 2023

Meanwhile, Pro-Environmental Behaviour has an R-square of 0.654, which means that the model for pro-Environmental Behaviour accounts for 65.39% of the variance in the dependent variable. Like Environmental Knowledge, this also suggests a good model fit for this variable.

The R-squared value, or the coefficient of determination, is a statistical metric used in regression models to represent the proportion of variance in the dependent variable that the independent variables can explain. This value ranges from 0 to 1, where higher values indicate a better fit of the model to the data. In this case, both variables have R-squared values above 0.65, suggesting that the models provide a significant explanation of the variance in the dependent variables. This implies that the independent variables are effective predictors of the dependent variables.

4.4 Hypothesis Testing

According to [49], [50], a path coefficient with a positive value indicates a positive relationship, while a negative value indicates a negative relationship. Additionally, according to [49], [50]A t-statistic value above 1.96 is considered valid, and a p-value below 0.05 is considered valid. Table 4 and Figure 2 present the results of the hypothesis testing.

The research findings demonstrate that the path from green training to environmental knowledge shows a strong positive relationship with an original sample estimate of 0.807. The T statistic is even higher (19.153), and the p-value is low ($0.000 < 0.05$), indicating a highly significant relationship. The result can support H1 statistically. The finding aligns with the research of [25]–[30] that examined the path from green training to environmental knowledge.

Table 4. Hypothesis Testing Results

Hypotheses	Path Coefficient	T-statistic	P-values α 0.05	Results
GT → EK	0.807	19.153	0.000	H1 Supported
EK → PEB	0.809	17.594	0.000	H2 Supported
GT → EK → PEB	0.652	10.148	0.000	H3 Supported

Source: Authors, 2023
Notes: GT: AR Green Training; EK: Environmental Training; PEB: Pro-Environmental Behaviour

The path from environmental knowledge to pro-environmental behaviour has a very high original sample estimate (0.809), indicating a strong positive relationship. The T statistic is very high (17.594), and the p-value is also low (0.000 < 0.05), suggesting that this relationship is highly statistically significant. The finding supports H2 statistically. The result supports the work [31]–[38] who explored how environmental education should impart both human-environment system knowledge and environmental action knowledge to foster pro-environmental behaviour.

This indirect path shows a positive relationship with an original sample estimate of 0.652. The T statistic is lower than the previous two paths but still quite high (10.148), and the p-value remains low (<0.000 < 0.05), confirming the significance of the indirect effect of green training on pro-environmental behaviour through environmental knowledge. The result is in line with the work of [39]. [41]–[43]. [43]. [44]. [40]. [41] [36] who found that environmental knowledge plays a pivotal role as a mediator in promoting pro-environmental behaviour and demonstrating its positive influence. However, several factors moderate the relationship between environmental knowledge and pro-environmental behaviour. Furthermore, environmental knowledge also moderates the influence of prosocial values and environmental attitudes on behaviour, highlighting its role in shaping behavioural outcomes.

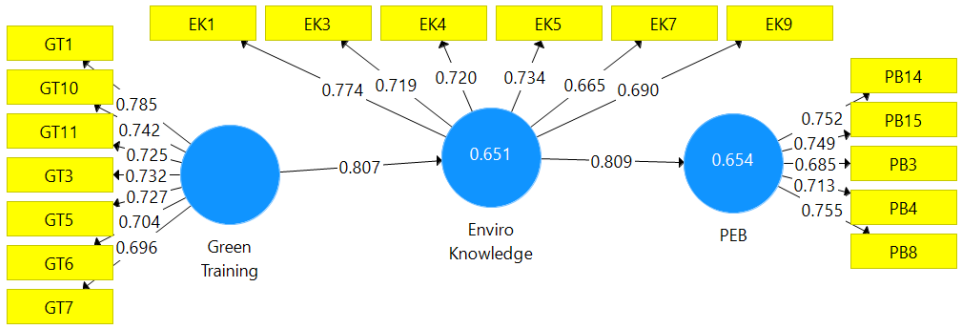

Fig. 2. Path Analysis Structural Model

These findings show that all direct and indirect paths of environmental knowledge and green training impacting pro-environmental behaviour are significant. Furthermore, what may also be viewed as very strong evidence for the positive relationships among these constructs is represented in high T-statistics with extremely low p-values across these paths.

4.5 Discussion

The strong connection between green training and environmental knowledge (O = 0.807, T = 19.153, p < 0.0001) further emphasises that educational and training programs are necessary to enhance environmental knowledge. This also aligns with educational theories, which hold that meaningful complex knowledge and skills must be learned from structured learning experiences.

A high positive correlation with environmental knowledge in PEB was found to reinforce the fact that increasing awareness goes a long way toward promoting sustainable actions. This finding supports theories positing knowledge and awareness as cardinal precursors of changing behaviours ($O = 0.809$, T-value = 17.594, $p < 0.0001$).

The indirect effect of green training behaviour was also found with $O = 0.652$, at $T = 10.148$, and $p < 0.0001$. As behaviour change models suggest, such programs increase knowledge and consequently impact behaviour; for example, the Theory of Planned Behaviour and Knowledge-Attitude-Behaviour model. The findings strengthen the role of educational interventions in environmental psychology and sustainability studies, as they show that such targeted training can actually induce knowledge gain and behavioural change. In terms of statistical support for these pathways, this will, therefore, further validate and reinforce models of behaviour change and, therefore, may suggest that future research could focus on other factors that might impact these relationships.

Theoretical Implications: Icek Ajzen's Theory of Planned Behaviour reveals that an individual's behaviour is best predicted by the intention, which, again, is determined or influenced by three major factors: attitude toward the behaviour, subjective norms, and perceived behavioural control. A recent study that examined the relationship between green training and environmental knowledge in predicting pro-environmental behaviour provided several insights into TPB.

In that regard, the results indicate a very strong positive association of PEB with environmental knowledge. To put it differently, this means that, based on green training, increased levels of environmental knowledge lead to improved attitudes towards PEB. This supports TPB's contention that attitudes are developed based on beliefs about the consequences of behaviours; the better one's knowledge, the more positive one's attitude toward performing PEB would be. The direct influence of green training on environmental knowledge suggests that educational efforts may alter perceptions of normative behaviours of social groups. Therefore, it can be inferred that green training programs affect subjective norms by modelling values and practices of environmental behaviour in community or organisational settings and inculcating them in their own behaviours because of the perceived pressure from a relevant social group.

The study also shows that improved environmental knowledge affects PEB and enhances perceived behavioural control by equipping people with skills and confidence to engage in PEB. In other words, transformation in abilities precedes transformation in behaviour. Perceived behavioural control, as proposed by the theory of planned behaviour, is an antecedent to intention and behaviour. Knowledge and skills enhance one's self-efficacy or the feeling of being capable of performing PEB and hence its likelihood.

The long-term implications of these findings for the design of interventionists or effective communication strategies can be very deep. Regarding this, training content needs to emphasise the positive outcomes of PEB to build more positive attitudes. Programs need group activities that could enhance a sense of community and shared values about how best to work towards environmental sustainability. Particular programs also need to provide participants with tools that will enhance their ability to undertake PEB, such as training in using energy conservation methods or waste reduction techniques.

Therefore, Communication strategies should be designed to align educational messages with constructs of TPB, emphasising community and personal benefits in a way that influences subjective norms and attitudes and diffusing manuals that demonstrate the ease of performance of specific actions to enhance perceived behavioural control. Such norms and perceptions can be further reinforced through testimonials or actions by peers or influential figures.

Lastly, it is important to consider alterations of attitudes, norms, and control before and after training to include the effectiveness of a program. Supportive feedback needs to be

maintained throughout the sessions to help maintain and enhance intentions toward performing PEB. This multi-element approach demonstrates how training interventions might readily address all antecedents within the TPB to shape intentions and behaviours powerfully.

Practical Implications: Developing a green training intervention enriched with AR using the theory of planned behaviour (TPB) effectively educates participants on green practices that can be implemented in everyday life.

Training Aims and Content:

- Objectives: Modify participants' negative attitudes about pro-environmental behaviours, support subjective norms regarding PEB, and increase perceived behavioural control associated with everyday life.
- Produce AR content and topics of interest to users in daily activities regarding recycling, energy conservation, saving water, and green commutes.

Choosing AR Technology:

- Platforms: Utilize accessible AR platforms, including mobile apps or even smart AR glasses.
- Software: Use AR development tools like Unity with Vuforia, ARKit, or ARCore to create interactive experiences.
- Hardware: Ensure the presence of the necessary devices, such as smartphones, tablets, or AR glasses.

Developing AR Content Aligned with TPB Constructs:

- Attitude: Develop AR simulations of sustainable practices that can be integrated into the environment and use a show-and-tell comparison to represent different behaviours.
- Subjective Norms: Introduce virtual role models and design AR experiences around community or group activities to create shared norms.
- Perceived Behavioural Control: Create interactive AR tutorials for practising sustainable behaviours and provide real-time feedback.

Integrating AR into the Training Program:

- Integrate AR experiences with traditional training methods, such as workshops and hands-on activities.
- Conduct workshops where participants interact with AR content and note their experiences.
- Add AR-based quizzes and assessment tools to provide on-spot feedback and grading.

Implement and Promote the Program:

- Pilot test to resolve technical issues.
- Organize periodic training sessions and assist the participants in using the AR content.
- Promote the program through various communication channels to showcase innovation in the use of AR.

Assessing and Enhancing the Program:

- Gather their feedback regarding their AR experience and how it influenced them regarding attitude, norms, and perceived control.
- Measure changes in knowledge, attitudes, norms, and behaviours with pre-and post-training assessments.
- Use feedback and performance data to refine the AR content and training methodologies.

Example AR Green Training Program:

- Objective: Encourage the maintenance of sustainable daily habits among employees.

- AR Modules for Attitude: Simulate water—and energy-saving actions and display the results to demonstrate both environmental and economic benefits.
- AR modules on subjective norms: Open the interaction with virtual peers endorsing sustainable practices, and initiate challenges within the AR-based community.
- AR Modules for Perceived Behavioural Control: The guide should include recycling guidelines and real-time energy use tips, making adopting sustainability easy.
- Implementation and Evaluation:
- Introduce it all with an introductory session on why daily sustainable practices are important.
- Offer the required AR tools and interactive workshops.
- Assess understanding and give feedback through AR-driven methods.
- Collect feedback on the AR experience and measure its effectiveness in terms of the behavioural change caused by the program.

When TPB constructs are embedded in a green training initiative on daily activities that use AR, the training is turned into a hands-on and engaging experiential learning process. Thus, it becomes very instrumental in effecting the change of sustainable behaviour. Not only will this approach enhance attitude, reinforce norms, and boost control, but it will also intervene in the interactive nature of AR to anchor participants' everyday life pro-environmental behaviours.

This research enhances the fields of environmental education and the Theory of Planned Behavior (TPB) by integrating immersive technologies like Augmented Reality (AR). By incorporating AR into green training programs, the study enhances environmental knowledge and stimulates pro-environmental behavior, offering immersive and interactive learning experiences that foster skill development and real-world application beyond traditional methods. Moreover, it supports the TPB framework by demonstrating that AR green training positively influences environmental knowledge, subsequently impacting pro-environmental behavior. This highlights AR's role in shaping key behavioral determinants —attitudes, subjective norms, and perceived behavioral control—thus reinforcing the TPB's relevance in environmental contexts. The practical application of AR in corporate environmental education illustrates how businesses can leverage technology to enhance sustainability efforts. By engaging employees in pro-environmental behaviors through AR, companies can develop a corporate training model that aligns with both TPB and sustainability objectives.

5. Conclusion and Limitations

The current research intended to provide more solid empirical evidence on the role of AR green training in enhancing environmental knowledge and pro-environmental behaviour among Indonesian white-collar workers. The results indicated that AR training was an effective tool to improve the understanding and retention of environmental practices, fitting well within the Theory of Planned Behaviour. Reinforcement of knowledge greatly increased the commitment toward sustainable actions.

The mediated relationship of AR training and pro-environmental behaviour through environmental knowledge underlines the importance of informed intervention. These findings suggest that deepening understanding of the environment by bringing employees into more immersive and interactive AR experiences could give rise to a set of deeper and more enduring behavioural changes. For example, this would be very important in Indonesian contexts since cities and corporate settings are the key positions where national sustainability agendas take place.

While these results are promising, they nevertheless also point to limitations that justify further prodding. First, the reliance on self-report measures and the eventual presence of common method bias have consequences for validity. Future research might explore this using longitudinal designs and other assessment strategies to examine the long-term effects that can be established through AR Green Training.

Moreover, the fast pace at which AR technologies are evolving means that continuous updating and adaptation will be needed for training modules to remain relevant to the changeable standards of technology and the environment. In this sense, this dynamic approach will be imperative in keeping AR Green Training relevant and a critical tool for growing an environmentally conscious workforce within Indonesia and beyond.

A study that thereafter not only confirms the effectiveness of AR in environmental education but also highlights the critical interventions that innovative training solutions have in tackling global environmental challenges. In other words, bridging technological advancement with sustainable development, AR Green Training is poised to turn how traditional approaches to environmental education are managed for behavioural change on its head.

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Authors' Contributions and Data Availability

MGH lead the research, overseeing conceptualization, methodology, software, writing (including the original draft preparation), and final review. **IT and KI** prepare the literature review and discussion and are responsible for writing, proofreading, and editing. **IT and KI** handle data collection, prepare the literature review, and are responsible for writing, proofreading, and editing.

Data availability

https://docs.google.com/spreadsheets/d/1WTsQZJCmXDB6FSmHmC4ja8YRqqsps5cb/edit?usp=sharing&ouid=103333082160155599462&rtpof=true&sd=true

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