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Application of multi-sensory virtual reality in health education of prostate cancer: a randomized controlled trial

Hao Fang[1], Sa Cheng[2], Seng Yue Wong[3*] and Kenny S. L. Cheah[4*]

Abstract

Background Virtual reality (VR) technology has emerged as an innovative teaching and training tool across numerous educational domains, yet its potential impact in community health education, particularly for culturally sensitive topics like prostate cancer (PCa), remains insufficiently explored.

Methods The aim of this study was to assess the effectiveness of a multi-sensory, learning-based VR health education tool (M-PCP) on PCa knowledge, cognitive load and satisfaction among men in the community. A parallel-group two-arm randomized controlled trial was carried out in a community center in Shandong Province, China. Ninety-six male subjects aged 45–75 years were randomly divided into two groups, the experimental group (VR-based M-PCP (48)) and the control group (traditional multimedia lecture (48)). Results included PCa knowledge (pre-test/post-test), cognitive load (mental load and mental effort), and satisfaction with the learning experience.

Results The VR-based method showed that the health knowledge of the learners was significantly increased (mean 22.34 vs. 18.76, $p = .003$, $\eta^2 = 0.087$) compared to health lectures, satisfaction was significantly higher ($p < .001$) and cognitive load was significantly lower (mental load: $d = 1.78$; mental effort: $d = 2.45$). All effect sizes (d) were medium to large.

Conclusions The findings indicate that VR technology can enhance the learning outcomes in the short term community health education around PCa awareness. Long-term retention, behavioral change and scalability into various settings should be explored in future research.

Keywords Virtual reality, Community health education, Multi-sensory education, Prostate cancer

*Correspondence:
Seng Yue Wong
wongsengyue@um.edu.my
Kenny S. L. Cheah
kennycheah@um.edu.my
[1]Institute for Advanced Studies, University of Malaya, Kuala Lumpur 50603, Malaysia
[2]School of Journalism and Communication, Northwest University, Xi'an 710127, China
[3]Academy of Malay Studies, University of Malaya, Kuala Lumpur 50603, Malaysia
[4]Faculty of Education, University of Malaya, Kuala Lumpur 50603, Malaysia

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Introduction

Health education is an important tool in public health, particularly in adapting to new health issues and supporting community health and well-being. In recent years, the scope of health education has been broadened to encompass chronic disease management, mental health and reproductive health [4]. In recent times, the role of health education in addressing public health emergencies has been highlighted, especially in the current COVID-19 pandemic [2]. Although traditional methods of health education (such as through lectures and printed materials) are effective in reaching a broad range of health consumers, they are not necessarily effective in meeting patient needs, which is often the case with culturally sensitive topics, such as prostate cancer (PCa) [34].

With the rapid advancement of digital technology, the traditional health education model has been transformed, and the application of digital technology has also broken through the constraints of traditional teaching methods [26]. In the health education field, virtual reality (VR) technology has been recognized as a disruptive force in the classroom, particularly for creating multi-sensory learning experiences for learners [43]. VR can be a powerful tool to engage the learner in medical concepts and practices that are difficult to understand and challenging to perform, promoting positive behavior change and ensuring cognitive engagement. Moreover, VR can offer the standard distance learning function, which is a revolutionary approach in health education [36].

While VR technology has been well established in the field of education and training, its use in community health education is still poorly researched, particularly in the context of culturally appropriate health education – e.g., prostate cancer awareness. Several social and cultural contexts have been associated with deep stigma around UGDs, such as PCa, which can significantly impede timely seeking of medical help for patients [6, 21, 37]. In many cultures, traditional gender roles are associated with traits of manliness such as emotional control and self-reliance. This lack of healthy choices also contributes to the delay and poor diagnosis and treatment, resulting in poor health outcomes for individuals and society's burden.

To respond to these challenges, effective health education tools need to integrate cultural sensitivity and background adaptability and provide targeted content design to effectively eliminate personal shame and encourage positive behavior changes. VR technology can be used to offer a new approach to community health education due to its immersive and interactive nature. VR can not only help learners to better understand complex medical concepts through a multi-sensory learning experience, but also let learners explore topics on cultural taboos with privacy and anonymity.

Research problem

Although the use of VR in the field of health education has been increased, there is a lack of empirical evidence on the effectiveness of VR in the community-based area of PCa education, especially in the culturally conservative environment where stigma may prevent engagement. Unfortunately, there is no rigorous study that compares a theory-based multi-sensory VR tool with a traditional multimedia lecture to increase knowledge, decrease cognitive load, and increase satisfaction among middle aged and older men within a community context. Given these existing research gaps, this study aims to design and develop a VR health education tool (M-PCP) based on the theory of multi-sensory learning.

Research focus

Based on multi-sensory learning theory, we designed and developed a VR health education tool (M-PCP) to address the above research gap. M-PCP offers a learning experience based on multi-sensory elements including anatomical models, video and audio explanations, interactive games in competition and interaction with virtual avatars, all supported by high fidelity graphics and immersive content, supported by head-mounted displays (HMDs). M-PCP seeks to tackle issues of stigma and deepen conceptualisation of health in a private and interactive setting. Additionally, this approach seeks to reinforce knowledge retention, decrease cognitive load, and increase learner satisfaction.

Research aim and research questions

Based on underpinned VR health education method, this study aimed to address the following three research questions:

> RQ1: Compared with traditional health education, does the VR-based M-PCP learning tool improve participants' level of PCa knowledge?
> RQ2: Compared with traditional health education, does the M-PCP tool reduce participants' cognitive load during learning?
> RQ3: Compared with traditional health education, does the M-PCP tool lead to higher learning satisfaction?

Literature review

Community health education: status and challenges

Community health education has been a primary component of public health approaches since its inception, designed to enhance citizens' health literacy, decrease health inequality and enable people to make healthy choices. World Health Organization (WHO) states that health education enables people to gain information, motivates them to take action about health and enhances

health literacy [40]. It is especially relevant in community settings, where social and economic disparities, cultural stigmatisation and lack of resources frequently can generate health disparities.

The use of traditional teaching methods like didactic lectures and printed material does not always reach various target groups. They are unable to deal with the various levels of culture and are not able to adjust to the unique cultural and social backgrounds, leaving little information retained and a diminished impact on the individual's behavior [31, 34]. Cultural stigma also exacerbates health inequity, particularly with respect to sensitive topics like PCa. Many of the societies have taboos around this topic, where people do not seek medical advice or take part in health education programs regarding urogenital health [6]. Traditional gender norms around masculinity and self-reliance, and emotional restraint, can feed into this stigma [37, 21].

The COVID-19 pandemic was an opportunity to test the ability of the traditional community health education approach and required a quick pivot to digital and distance learning. Digital platforms like online webinars, mobile apps, and distance health services have demonstrated the capacity to reach a broader audience and bridge geographical gaps [31, 34]. But there are still gaps that need to be addressed, such as access to smartphones and high-speed Internet, and digital literacy differences [25].

Application of VR technology in community health education

Since VR provides learners with an immersive and engaging learning experience, recent research has focused on the potential of VR in health education. VR supports cognitive processing and knowledge retention by modelling real-world situations and providing multi-sensory input (visual, auditory, tactile) to the learner, especially when dealing with complex medical concepts [8, 9]. It has been used in managing chronic diseases, rehabilitative care, mental health and clinical training [17, 12].

A key advantage of VR is the potential for standardizing instruction while still providing flexibility to meet individual learners' needs and ensure high quality instruction in any environment [10]. It has been established that gamification features in VR can help enhance the motivation and engagement of the learners and promote the retention of information [41]. Another advantage of VR is that there's a private learning environment, which is also significant for sensitive health-related issues like prostate cancer. Virtual consultations allow the ability to communicate with medical practitioners in a secure and anonymous setting [6].

However, there remain barriers to the application of VR in the community, such as cost, technical complexity and access, particularly in resource poor communities [35].

Multi-sensory learning theory and virtual reality

The Multi-Sensory Learning Theory (MSLT) suggests that the educational outcomes are better when education is offered through multiple sensory pathways at the same time [32]. The MSLT theory is based on cognitive science, which indicates that people learn and remember better when they utilize more than one sensory modality (visual, auditory, kinesthetic and tactile) to process and remember information than they do with just one [19]. The neurological basis is superadditivity, that is, convergence of sensory information leads to increased neural responses [22, 24]. Neuroimaging studies show that multi-sensory learning activates numerous brain regions, enhancing neural connections and memory formation [32].

MSLT is based on existing theories such as Dual Coding Theory [28] and Cognitive Load Theory (CLT) [33]. CLT defines the differences between intrinsic load (because of the complexity of the material itself), extraneous load (because of the way it was taught), and germane load (because it is being thought about and processed productively). The traditional health education usually gives high extraneous load, since learners are required to mentally transform 2D health education representation into 3D understanding. VR offers content in 3D space, which minimizes the excess load and releases cognitive resources [16, 27].

VR technology is a strong tool for multi-sensory learning because it is able to involve multiple senses in the learning environment [30]. VR can engage the senses of touch, proprioception and spatial awareness besides the traditional visual and auditory senses [13]. Empirical evidence shows that VR is effective: Makransky et al. [16] demonstrated that immersive VR increased knowledge retention over desktop simulations and Johnson-Glenberg et al. [14] confirmed that embodied VR learning led to better conceptual understanding.

The key benefits of multi-sensory VR for health education are providing support for learning anatomical concepts and medical procedures, reducing cognitive burden, and providing support to a wide range of learners [23, 42]. Thus, emotional involvement promotes learning outcomes [38] wheras VR can be used to develop psychologically safe spaces, which are characterized by decreased anxiety and defensive reactions, especially in the context of sensitive topics like prostate cancer [29].

M-PCP: community health education model supported by virtual reality

The M-PCP tool embodies the potential of VR to change community health education for PCa. M-PCP is grounded on the multi-sensory learning theory and consists of 4 stages, i.e., a PCa science video (Visual), interaction with a virtual doctor (Auditory), interaction with a 3D anatomical model (Vibrotactile/Kinesthetic), and a virtual competitive game (Kinesthetic). The design is a perfect fusion of technology and culture.

As Fig. 1 depicts the researcher's scenario design interface for the M-PCP learning system using the Unity 3D platform, the system designers provided an inclusive learning experience for the learners. Firstly, M-PCP emphasizes cultural relevance and enhances the acceptability and participation of the audience by incorporating localized content. For example, educational videos are produced by local healthcare personnel and presented in local languages, thus enhancing the credibility and relevance of the content [51]. This personalized design improves the cultural adaptability of M-PCP as an educational tool and helps learners eliminate cultural barriers in health topics.

Secondly, most notably, as shown by Fig. 2a, M-PCP solves the social stigma related to discussing the health problems of the urogenital system by setting up virtual consultation, because it provides a private and anonymous learning environment for learners to interact with the content through virtual image or virtual consultation without worrying about social evaluation. This way aims to promote learners' learning enthusiasm and sense of participation. The third point is that M-PCP created a fascinating educational environment by using high-fidelity 3D models, gamification learning modules and interactive tests (see Fig. 2b).

Compared with traditional methods, this multi-sensory learning design enhances learners' understanding of complex health concepts and their ability to retain knowledge [8]. The theoretical basis of multi-sensory learning emphasizes the importance of visual, auditory and tactile interaction in stimulating learning motivation and improving cognitive performance [39]. Finally, M-PCP's design has taken into account a broad applicability. Learners can learn on various platforms such as VR headsets, PC ports and smartphones. Meanwhile, the system also enables multiplayer online games for 5 or more players and enables users to select their avatars, with personalisation also supported and voice chat enabled. This flexibility enables it to operate in different community scenes in China, thus expanding the coverage

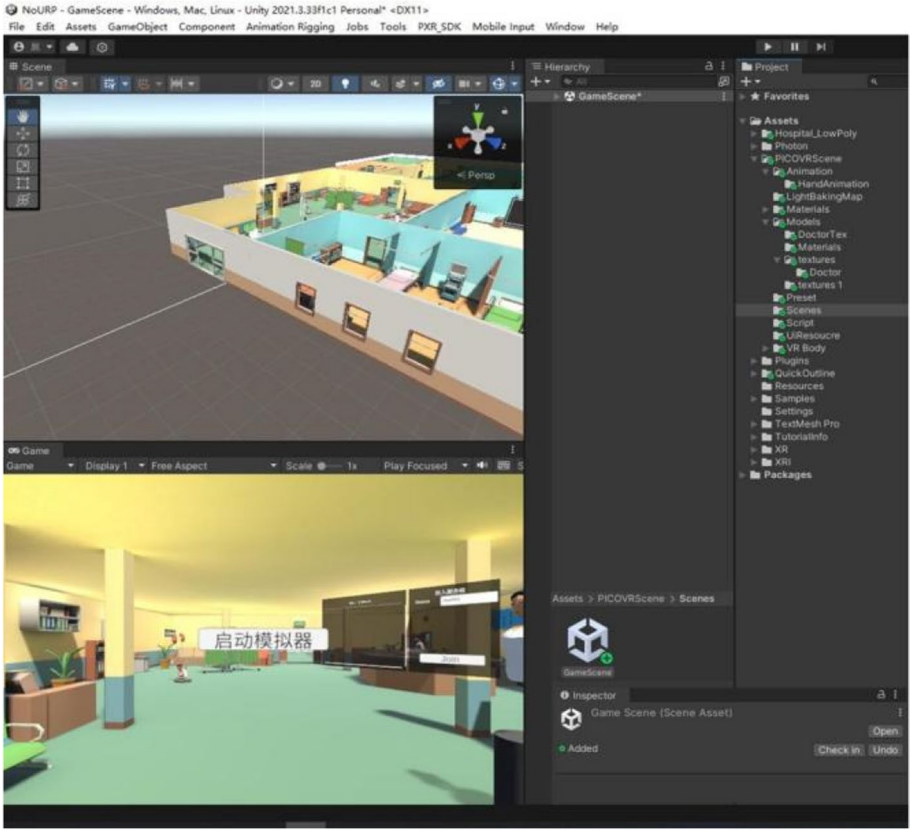

Fig. 1 Scenario design interface for M-PCP

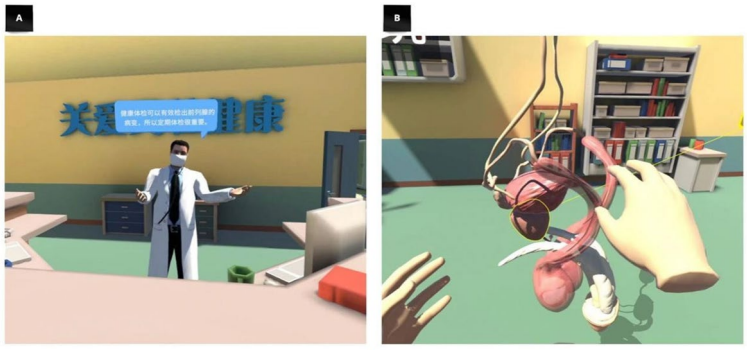

Fig. 2 Examples of interaction in M-PCP learning system (**a**) Virtual dialogue (**b**) 3D model

Table 1 Sample information

Characteristic	Total sample (*n* = 96)	Experimental group (*n* = 48)	Control group (*n* = 48)
Age Range (years)	45–75	45–75	45–75
Gender	Male (100%)	Male (100%)	Male (100%)
Health Status	Intact sensory abilities Intact sensory abilities include vision, hearing, and touch as specified in the inclusion criteria	Intact sensory abilities	Intact sensory abilities
Prior PCa Education	None (100%)	None (100%)	None (100%)

Technology Familiarity was measured on a 5-point scale (1 = not familiar at all, 5 = very familiar)

*Health Literacy Score was measured using the validated Chinese Health Literacy Scale (Wang et al., 2018) with a range of 0–30 points

of the audience. The designs also continue to highlight the potential of VR as an effective and applicable learning tool in the community health education field, moving forward.

Research methodology

General background

This research used a randomized controlled trial (RCT) with two arms and a parallel group design to evaluate the effectiveness of a VR health education program in a community. The design allows for good comparison of experimental and control conditions, and allows for practical considerations of community-based research to be taken into account.

Participants

Based on a priori power analysis performed in G*Power 3.1 [7] and an expected medium effect size (f = 0.25), alpha = 0.05 and power = 0.80 for a two-group comparison with repeated measures, the minimum sample size required was 86 participants. For possible attrition, we recruited 96 participants (48 in each group).

As shown in Table 1, The sample consisted of 96 men, aged between 45 and 75 years (M = 59.7, SD = 8.3) attending a large community center in the northern part of China. The inclusion criteria were: No prior PCa education or training and intact sensory capabilities (vision, hearing, touch). Written informed consent was obtained for all participants.

The computer-generated random number sequence was used to allocate participants randomly to the experimental group ($n = 48$) or control group ($n = 48$) at a 1:1 ratio. Allocation concealment was achieved through the use of a research assistant who was not involved with the recruitment of participants or assessment process. Pre-test and post-test evaluators were blinded to the group allocation.

The experimental group engaged with the M-PCP VR tool using VR headsets. The traditional multimedia course was a health-talk by experts which covered the same material as the VR tool, and was provided to the control group. The experiment was done with the guidance of three medical experts (two urogenital surgery, one health management) and two education professors.Three medical experts (two urogenital surgery, one health management) and two education professors guided the experiment.

Withdrawals were allowed at any time. Academic research ethics and the Declaration of Helsinki were followed in all procedures. No participant requested to drop out.

Experimental design and procedures

As shown in Fig. 3, the procedure started with an introduction and guidelines (30 min) and then included a pre-test (20 min) for baseline knowledge of PCa. The experimental group was administered with M-PCP and the control group was administered with the multimedia lecture for 45 min for the learning phase. All participants then took post tests, cognitive load assessments, and satisfaction questionnaires (40 min) after learning.

Content equivalence was satisfied by having the same content checked for equivalence by experts, time

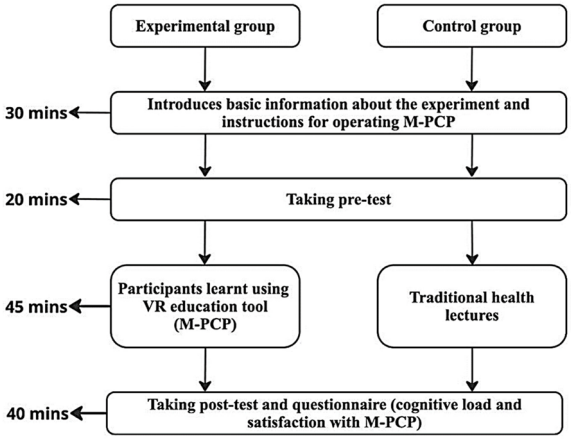

Fig. 3 Experimental procedure

equivalence by having a 45 min time to test, instructor equivalence by using a standardized script with the same educator for the same control group, novelty effect control by familiarizing the experimental group with technology for 15 min prior to the test, and environmental control by testing in the same room, lighting, temperature, and noise. The same conditions were used for all assessments.

Detailed description of the M-PCP intervention

To ensure reproducibility, the following detailed description of the M-PCP intervention is provided:

The learning objectives were to; know the normal anatomy of the prostate and its position, identify the early signs and symptoms of prostate cancer, know the importance of regular screening (PSA test, DRE), and to minimize fears and stigma around talking about urogenital health.

The order of modules and time comprised the following components. Module 1 (visual) comprised an educational video of 10 min in local Shandong language, which summarizes the epidemiology, risk factors and symptoms of PCa. Module 2 (auditory/interactive) comprised a case study including a virtual doctor with a 10 min dialogue where the participant can ask the questions by selecting a multiple choice and receive verbal answers. The 3D anatomical model is explored for 15 min, in module 3 (vibrotactile and kinesthetic). Using hand controllers, participants rotate, zoom and dissect virtual prostate tissue. When touching key structures, controller vibration (vibrotactile feedback) is generated. There is no real 'haptic/tactile texture' feedback. Whereas, module 4 (gamified) comprised an 10-min competitive quiz that students will compete against virtual opponents with points being earned for correct answers and feedback provided immediately.

Hardware and softwares included Head-mounted display: HTC VIVE Pro Eye, Platform: Unity 3D (version 2020.3), Runtime: SteamVR, Controllers: HTC VIVE vibration feedback controllers.

Sensory channels engaged were Visual (high-resolution stereoscopic 3D), Auditory (spatialised voice, sound effects), Kinesthetic (head and hand movements tracked) and vibrotactile (controller vibration when interacting with things). There is no real haptic (force, texture) feedback; we have corrected terminology accordingly.

Accordingly, participant support contained the research assistant stayed in the room, gave consistent instructions prior to each module and demonstrated to participants a visible "pause/stop" button on the controller. Participants' comfort was checked on every 5 min by assisting verbally.

Measurement instruments

Health knowledge test based on multiple choice test with 15 questions (2 points each correct answer – maximum 30 points) was used. The same questions were presented on the pre-test and post-test, but the order was different. The test was created by a urogenital expert and confirmed by two health administration professors.

Cognitive load scale is adapted from the cognitive load scale developed by Hwang et al. [11], which is based on two dimensions: mental load (3 items) and mental effort (3 items), all on a 5-point Likert scale. The Cronbach α values are 0.85 (mental load) and 0.86 (mental effort) in the current sample.

Satisfaction questionnaire based on two identical questionnaires were administered. Items for the experimental group were: For example, I am satisfied with the M-PCP tool for learning about PCa. The control group included items that were related to the multimedia lecture (e.g., "I am satisfied with the multimedia lecture for learning about PCa"). Both used an instrument with 5-point Likert scale developed by Li et al. [15]. In the current sample, Cronbach's $\alpha = 0.91$ (experimental group) and 0.88 (control group).

Ethical and safety considerations

The cybersickness screening consisted of inquiring about previous VR experiences and motion sickness sensitivity before participants were recruited. Two people who reported they suffered from severe motion sickness were excluded.

The research assistant verbally monitored for adverse events every five minutes during VR was used for adverse event monitoring. No participants reported cybersickness or other negative side-effects. There was a visible Pause/Stop button and participants were told they could pause/stop at any time.

Table 2 ANCOVA for learner's health knowledge level

Group	N	Mean (SD)	Adjusted mean	SE	F	p	η^2
Experimental (VR)	48	14.92 (11.28)	22.34	0.54	8.92	.003	0.087
Control (lecture)	48	11.27 (7.87)	18.76	0.54			

Possible score range 0–30. F(1,93) = 8.92. η^2 = partial eta squared (medium effect)

Table 3 The t-test result for learner's cognitive load levels

Variable	Group	N	Mean	SD	t	*p*	Cohen's d	95% CI for d
Mental load	Experimental (VR)	48	8.35	3.57	−10.82	<.001	1.78	[1.30, 2.25]
	Control (lecture)	48	19.88	2.57				
Mental effort	Experimental (VR)	48	6.00	2.73	−20.00	<.001	2.45	[1.94, 2.95]
	Control (lecture)	48	12.23	2.25				

Both scales range from 3 to 15 (higher scores = higher cognitive load). df = 94 for all t-tests

Table 4 The t-test result of the learner's satisfaction degrees

Group	N	Mean	SD	t	p	Cohen's d
Experimental (VR)	48	40.75	3.30	35.26	<.001	7.21
Control (lecture)	48	14.87	3.12			

Satisfaction scale range 9–45 (higher scores = higher satisfaction). df = 94

There was explicit written informed consent that participants were allowed to withdraw without penalty and none of them withdrew.

All responses to the questionnaires and interactions with the VR were anonymised with participant codes for data privacy and anonymisation:. The data were collected and kept on a password protected server of the university which only the research team could access.

Data analysis

SPSS version 26 was used for all analyses. One-way analysis of covariance (ANCOVA) was used to evaluate the differences in the posttest knowledge between the groups, with the pretest knowledge as a covariate. Accordingly, independent-samples t test was used to compare the cognitive load and satisfaction. Effect sizes: partial η^2 (ANCOVA), Cohen's d (t-test) and level of statistical significance of $\alpha = 0.05$ (two-tailed) were used.

Research results

Baseline equivalence

This was achieved by successful randomization, as no significant differences were obtained between groups in age ($p = 0.62$), familiarity of technology ($p = 0.45$), health literacy ($p = 0.51$), or pre-test PCa knowledge ($p = 0.73$).

Health knowledge level

The ANCOVA results for post-test PCa knowledge controlling for pre-test scores are shown in Table 2 which postulates that learning methods based on VR can effectively improve learners' academic performance. The experimental group (VR) had significantly higher adjusted post-test knowledge (M_adj = 22.34, SE = 0.54) than the control group (M_adj = 18.76, SE = 0.54), F(1, 93) = 8.92, $p = 0.003$, partial $\eta^2 = 0.087$ (medium effect). The VR-based M-PCP tool helped to enhance PCa knowledge in comparison to conventional education, giving a clear answer to RQ1.

Cognitive load

This study used a cognitive load questionnaire that primarily evaluates two aspects of the learners' educational experience: "Mental load" and "Mental effort". Through an independent t-test, the researcher explored the influence of learning methods based on VR technology on learners' cognitive load in learning activities.

The t-test analyses of mental load and mental effort are presented in Table 3. The experimental group reported significantly lower mental load (M = 8.35, SD = 3.57) than the control group (M = 19.88, SD = 2.57), t(94) = −10.82, $p < 0.001$, Cohen's d = 1.78 (large effect). Similarly, mental effort was lower in the experimental group (M = 6.00, SD = 2.73) than in the control group (M = 12.23, SD = 2.25), t(94) = −20.00, $p < 0.001$, d = 2.45 (very large effect). The result of this finding provided an answer to RQ2: the VR tool significantly reduced the cognitive load.

Satisfaction with the two learning styles

The satisfaction questionnaire used in this study was designed to assess learners' perceptions of the use of the M-PCP learning tool. To assess the satisfaction of the learners in both groups, the researcher conducted a *t*-test.

As shown in Table 4, the experimental group had significantly higher satisfaction (M = 40.75, SD = 3.30) than the control group (M = 14.87, SD = 3.12), t(94) = 35.26, $p < 0.001$, d = 7.21. This addresses RQ3: participants were more satisfied with the VR based learning experience.

Discussion

In this randomized controlled trial we created a multi-sensory health education tool (M-PCP) using VR to educate community-dwelling men about prostate cancer. The findings reveal that significantly, M-PCP increased student satisfaction, decreased cognitive load and promoted short-term knowledge when compared with a traditional multimedia lecture.

The increase in knowledge is in line with previous research that has demonstrated that multi-sensory VR has a positive impact on cognition and memory [3, 39]. The 3D anatomical models and the 3D visuals in M-PCP enabled participants to explore 3D anatomy instead of 2D models and gave them the opportunity to listen and ask questions, while also gamifying the quizzes. This is in line with constructivist theory whereby students build their knowledge by experiencing it [1]. Our results build upon previous research showing that VR can be an effective teaching tool for medical students, and further, that the VR can be used with members of the community, in this case older adults, who have no prior PCa education.

The large change in cognitive load (d = 1.78 for mental load, 2.45 for mental effort) supports predictions made by the Cognitive Load Theory. The traditional multimedia lecture has high extraneous load for learners to integrate various visual and auditory information in their mind. VR is the presentation of spatially and temporally aligned information in one 3D space, which minimizes split attention effects [16, 20]. In addition, the multi-sensory design (visual, auditory, kinesthetic, and vibrotactile) may have allowed automatic integration of the information that would leave germane resources for deeper processing [18].

The reason of M-PCP's high satisfaction may be attributed to the nature of the VR experience which is engaging, game based and private. For tackling a "stigmatized" topic, participants were grateful that there was no social evaluation. The result aligns with Cheng et al. [5] who observed the correlation between cognitive load and satisfaction. The interactive and immersive design likely accounted for the greater intrinsic motivation and perceived enjoyment.

The findings corroborate those of Makransky et al. [16] who concluded that immersive VR resulted in lower extraneous cognitive load than desktop VR. They are also consistent with the findings of Moro et al. [23] which showed that multi-sensory VR enhanced the learning outcomes of anatomy. In contrast to the above studies that were conducted with university students, our participants were older adults with minimal prior VR experience and indicate that VR can be effectively utilized across the lifespan with proper familiarization and support.

Limitations

Although this study has made remarkable achievements in health education, there are still some limitations to be noted. The sample was small and comprised only the community in Shandong Province and therefore, generalizability to other regions or populations should be tested further. Second, the intervention was short (45 min) and immediate post-test results were measured. Long-term knowledge retention, actual screening, reduction of stigma and health outcomes were not evaluated. Third, the VR system employed was quite basic (i.e., no true haptic feedback) and the material included only prostate cancer. Fourth, the pre- and post-test were identical in content, but of course the questions were randomized (and the effect size was still large, so simple recall of them is unlikely), which also suggests the potential for memory effects. Fifth, there may be cost and technical considerations to implementation in resource-poor communities. Delayed post-tests, behavioural measures (e.g., screening uptake), culturally adapted versions for regions, and low-cost VR solutions should be included in future research.

Conclusions and implications

This study is an initial step in demonstrating that a theory-based, multi-sensory VR tool (M-PCP) can be used to enhance prostate cancer knowledge, decrease cognitive load and increase satisfaction among middle aged and older men in a community setting. The results indicated that VR could be used as a private, engaging and effective way to provide health lectures on sensitive health issues instead of traditional lectures.

But these findings are not yet evidence of long-term retention, behaviour change or public health impact. Future studies should determine the impact of knowledge acquisition on increased screening uptake, decreased stigma, and better health outcomes. Further studies are needed on low cost VR solutions, other stigmatized conditions (testicular cancer, breast cancer, cervical cancer), and of integrating with AI for personalized learning.

VR modules for male health education could be implemented in community health centers, as long as they have the technology and resources available. VR could play a role in achieving health equity when implemented with continued refinement and improvement, providing uniform, culturally responsive education to people of all backgrounds.

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Not applicable.

Authors' contributions

HF contributed to study conception, design, performed the analysis and drafted the manuscript. SC follow-up assessments and data collection. SYW and KSLC participated in the design and development of this research, and supervised the research and ensured the accuracy of the research data,both

authors contribute equally to this work. All authors have read and approved the submitted manuscript.

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Data availability
Data can be accessed on request directed to the corresponding author.

Declarations

Ethics approval and consent to participate
Ethical approval was obtained from the University of Malaya Research Ethics Committee (UMREC)(UM.TNC(P&I)/UMREC_ 5129). Written informed consent was obtained from the participants. The study adhered to the Declaration of Helsinki.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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