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Evaluating the Use of Mixed Reality in CSI Training through the Integration of the Task-Technology Fit and Technology Acceptance Model

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ABSTRACT Despite the emerging literature on adopting Mixed Reality (MR) headsets in crime scene investigation (CSI) ¬, it is still debatable on how to employ these headsets and its application for training purposes in higher education and police academies. Hence, this research presents a novel hybrid theoretical framework that combines the Task-technology Fit (TTF) and Technology Acceptance Model (TAM) variables and the most prominent features of MR headsets—immersion, interactivity and mobility. The main objective is to explore young investigators' behavioural intention to adopt MR headsets and their applications for investigation training practices. To validate the developed model, a questionnaire survey was the primary method used to collect data from 160 police academy students using the partial least squares-structural equation modelling (PLS-SEM) technique. The empirical results revealed that task technology fit has a positive impact on the perceived usefulness of MR headset applications and no significant positive impact on the perceived ease of use applications of MR devices. On the contrary, individual technology fit has a positive impact on the perceived ease of use and no significant positive effects were found regarding the perceived usefulness of investigation training purposes. Furthermore, the results indicated that the mobility of MR wearable devices positively influences the perceived ease of use and the perceived usefulness for crime scene practices. The study also addresses the theoretical contributions and practical implications of these outcomes.

INDEX TERMS Crime Investigation Training, Task-technology fit, technology acceptance model

I. INTRODUCTION

In the realm of modern law enforcement, the ability to effectively investigate and analyse crime scenes is of paramount importance. Crime scene investigators (CSIs) are tasked with gathering crucial information and recreating difficult circumstances in order to aid in the pursuit of justice [1]. Given the delicate nature of their work, it is essential to provide CSIs with thorough, hands-on training that prepares them for the challenges and complexity they may run across in the field.

Technological advancements have consistently reshaped various industries, particularly law enforcement, by revolutionising how tasks are performed and pushing the boundaries of what was once possible. The CSI, with its constant pursuit of innovation and improvement, has been significantly impacted by these technological developments. In order to improve and refine the training process, academics and practitioners utilised cutting-edge technologies after realising the crucial role that training plays in providing CSIs with the essential skills and knowledge to enhance and optimise the training process. One of the most promising new technologies for transforming and revolutionising CSI training is MR [2]. MR offers a unique and captivating environment that blurs the boundaries between the virtual and physical worlds. In this hybrid environment, users are immersed in a simulated reality that combines virtual elements with real-world surroundings, creating a heightened sense of presence and interactivity [3]. A previous study examined the effectiveness of mobile computing in CSI through the theory of TTF; it was noticed an improvement in their process with an increase in the time consumed to operate it [4]. Researchers have recently begun utilising immersive technology to support crime scene investigation practices, particularly in training. Virtual Reality (VR) technologies offer unique opportunities for crime scene investigations that are not available in the real world. They allow for analysis of the scene and accurate measurements of its dimensions from various perspectives [5], thereby enhancing the amount of information that can be gathered during the investigation [6]. Immersive technology solutions have been developed specifically for crime scene training. One VR application, for example, supports practical skills training by providing simulations that overcome the limitations of cost, accessibility, and size associated with real crime scenes [7]. However, this application relies on computer-generated environments and may cause motion sickness during training. Another VR application employs a game-based learning approach in artificial environments to teach criminal law [8]. Furthermore, a conceptual framework has been developed to train digital forensic investigators in incident response, offering immediate performance feedback to each trainee [9].

The technology acceptance model (TAM) was validated in previous literature that explored the adoption of immersive technologies in training methods in different contexts [10-12]. Despite that fact, there is an insufficient amount of studies considering the validation of the model for using mixed reality devices and their applications in crime scene investigation practices considering the factor of behavioural intention [13, 14]. Moreover, there has been an indication that factors such as mobility can enhance the effectiveness and practical usage of wearable devices [15, 16]. Also, several studies emphasised that the immersion factor – described as an aesthetic experience – positively impacted the usefulness and perceived ease of use [17]. Previous literature suggested the role of the mentioned factors in the adoption of immersive wearable devices; however, their impact is expected to vary in the specific context of this study [18, 19].

Researchers found that integrating TAM model and TTF theory can influence the adoption of technological tools that support training activities [20]. Other scholars concluded that integrating both frameworks enhances understanding of the training tool [21]. Integrating both frameworks led to predicting behavioural and future learning intentions [22, 23]. Other scholars found that the integration of TAM and TTF led to enhance student satisfaction and academic performance[24]. TTF supported the acceptance of the technological tool among students when the study investigated TTF framework combined with TAM and other factors such as enjoyment, usefulness, convenience, mobility and social influence [25]. In spite of the conducted literature, the integration between both frameworks TTF and TAM is not explored in the context of CSI training with its unique nature using mixed reality devices and its applications.

In light of these arguments, this research aims to address the disparities in existing literature concerning the use of MR applications for crime scene training purposes and its impact on young investigators' performance in police academies. This study presents a novel model that combines TTF theory with the TAM model in the particular context of CSI training, providing valuable insights. By integrating TTF theory and the TAM model, this research also contributes to the advancement of MR hardware and its applications, fostering interest in future usage. The study highlights the effectiveness of spatial mapping, 3D scanning, photogrammetry technologies and the sense of presence combined with the interaction with virtual environments capabilities in promoting better crime scene investigation training. To enhance the investigation performance in policing students, the study recommends utilising mixed reality and its applications combined with 3D scanning technologies based on TTF and TAM theories to understand trainees' behavioural intentions and task-technology fit. The model proposed in this research can be applied to evaluate the practical usage of mixed reality in connection with TTF, Individual Technology Fit (ITF), perceived interactivity, and mobility, benefiting students and young investigators across various institutions and policing academies. Notably, the study emphasises the importance of disseminating knowledge about using mixed reality and its application for crime scene investigation training through TTF, as it has the potential to positively impact practical and academic progress in higher education. Ultimately, the integration of TTF and students' behavioural intentions to use MR applications for practising investigation enhances the academic experience of higher education students and contributes significantly to TAM research that previously did not fully consider the impact of mixed reality applications on investigation practices.

II. CRIME INVESTIGATION TRAINING

Providing on-site training to young investigators presents a difficult undertaking as it involves handling sensitive crime scenes, where there is a risk of trainees unintentionally compromising evidence due to their inquisitiveness or lack of experience. Contamination or tampering with the scene may occur, causing crucial evidence to be lost. Additionally, a high presence of people at a crime scene can impede effective investigations and raise the likelihood of disturbing hidden evidence [26]. Furthermore, certain crime scenes may not be accessible for wheelchair students [7]. Certain students have

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voiced challenges in staying up to speed with the rapid movements and processes occurring at crime scenes, which hampers their ability to observe effectively. [27]. Although certain educational institutions offer crime scene facilities for students to practice, it is not feasible to provide individual investigations to a large number of students at various academic levels and scenarios within a single facility. [7]. Police academies encounter challenges when it comes to offering context-oriented activities during the investigation and forensic training, primarily because they have a large number of trainees [28].

Therefore, the literature showed that immersive realities with the privilege of interactive environments can overcome the previous challenges and contribute to crime scene investigations. A study adopted immersive technologies for practising evidence collecting from crime scenes, which is considered a significant element during crime scene investigation [29]. Immersive technology can be employed in multiple ways, such as offering 360-degree panoramic views of three-dimensional environments within a mixed reality context, as these applications aim to enable distant investigators to collaborate effectively [30]. Building on the notion of MR collaboration as a distinguished capability in CSI training, additional researchers evaluated the potential applicability of collaborative interactions using MR devices in the field of forensics [31]. Earlier research has utilised Augmented Reality (AR) to encourage cooperation among distant forensic teams, consequently enhancing their understanding of the situation [32, 33]. Scholars discovered that integrating immersive technology into crime scenes can enhance these spaces using storytelling and fiction and for training purposes [34].

Several well-known authors in the realm of immersive technologies have suggested that MR and AR can be used interchangeably to some degree. They believe that MR offers more interaction with real-world surroundings and a heightened level of engagement [35]. Based on this consideration, the literature also encompasses research AR in the context of training for crime scene investigation. Nevertheless, most of these studies have been specifically tailored for smartphones and portable devices. For instance, there was an AR pilot research conducted, which employed a gaming method to enhance the forensic training experience [36]. AR applications are also developed for forensic education purposes, using AR tags to overlay virtual objects onto real environments for smartphone users [37, 38]. Recent studies have investigated markerless AR app usage [39-41]. In regards to immersive hardware and tools, several recent studies and industrial uses have concentrated on utilising AR and MR headsets like Microsoft HoloLens and Magic Leap for crime scene training [42, 43].

Law enforcement, police academies, and educational institutions worldwide are increasingly using virtual reality simulations to train for crime scene investigation [7, 44-46]. Even with the advancements made so far, there is still a noticeable absence of simulators that make use of MR technology to enhance immersion and the realistic experience of training for learners. This involves allowing them to navigate within a digitally recreated crime scene and engage with it in a way that closely imitates real investigative processes.

III. THEORETICAL MODEL AND HYPOTHESES

The current investigation introduces a theoretical framework that thoroughly examines various factors associated with the Task Technology Fit (TTF) theory. These factors encompass individual technology fit, in combination with the pertinent elements from the Technology Acceptance Model (TAM), including perceived usefulness, perceived ease of use, and young investigators' intention to adopt mixed reality devices and their applications. Additionally, more extrinsic factors that are related to the MR devices, such as mobility, perceived interactivity and immersion, were integrated into the proposed framework. These identified factors are subsequently observed to exert a consequential influence on the behaviour intention to the adoption of these technologies within police academies and higher education institutions. A detailed examination of these factors is presented within this section through a theoretical model, and its hypothesis is depicted in Figure 1.

A. TASK TECHNOLOGY FIT (TTF)

1) TASK TECHNOLOGY FIT (TTF)

In order to study the inclination of young investigators to adopt mixed reality devices and their applications, it's essential to look beyond just their interaction with the device and also consider the specific tasks-oriented practices linked with it. Based on this premise, the key to assessment when assessing the device adoption should take into account both the individual technology fit and the task-technology fit [21, 47].

a: Individual-technology fit (ITF)

The relationship between people's engagement and interaction with technologies often ties back to their adaptability behaviour to such technologies [48]. The functions of these technologies align with individual abilities and the demands of tasks [21]. Earlier research by Wu and Chen [21] indicated that when there's a good fit between a person and the technology, there's a perceived increase in its usefulness and ease of use, especially in the context of Massive Open Online Courses (MOOCs). Additionally, aligning technological features with individuals' requirements notably influences their outlook and usage. Beyond the alignment of technology with a specific task, it's crucial to ensure that the features of the technology align with users' needs. This alignment significantly influences an individual's perspective and use of the technology, as highlighted by several studies [48-52].

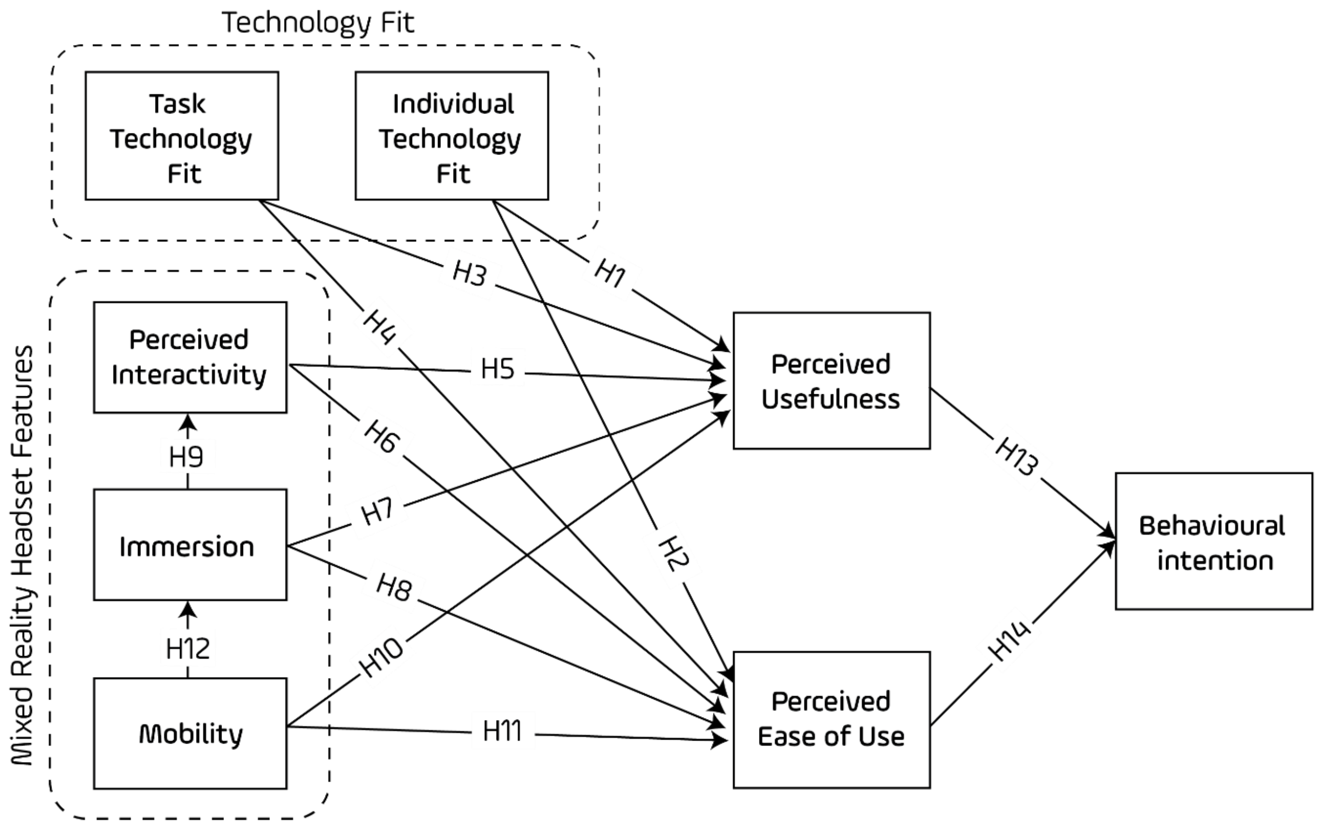

FIGURE 1. Research model and hypotheses

Therefore, if technology is tailored to fit individuals' learning preferences and capabilities, its adoption and effective use are more likely. In this research, the term ITF is understood as the compatibility of online technology features in the MR applications' platform with the unique learning styles of individuals. When there's a strong match between the technology and users' learning methods, it increases the likelihood of the technology being utilised, as explained by [53]. Therefore, it is suggested the following hypothesis:

H1. Individual-technology fit has a positive influence on the perceived usefulness of MR in CSI training.

H2. Individual-technology fit has a positive influence on the perceived ease of use of MR in CSI training.

b: Task-technology fit (TTF)

TTF indicates the extent to which a particular technology aids an individual in carrying out a specific set of tasks. Generally, it can be utilised in any condition where individuals employ technology to execute particular tasks [54]. It is defined as the alignment between a task and the capabilities of the technological device, or the system plays a significant role in determining job performance outcomes [55]. Past empirical research, such as the study by Pal and Patra [20] and Jung, et al. [56] concluded that the alignment of technology with users' current values, specifically perceived ease of use and perceived usefulness, construct their views on using and adopting that technology. Additionally, these studies have shown that task-technology fit impacts the perceived ease of use and perceived usefulness. In other words, the better the alignment between the task and the technology, the more likely users are to find it user-friendly and beneficial for that task. The features of a technology play a role in the effectiveness of VR headsets. It is concluded from the literature that the perceived value of the study context, which is CSI training through MR devices, hinges on users finding a match between the task and the technology. The tendency of users to willingly adopt MR devices and their associated applications for training is probably driven by how well the task aligns with the technology, influencing their perception of how easy MR headsets and applications are to use. Based on this, it is suggested that the subsequent study hypotheses:

H3. Task-technology fit has a positive influence on the perceived usefulness of MR in CSI training.

H4. Task-technology fit has a positive on the perceived ease of use of MR in CSI training.

B. MR HEADSET QUALITIES

Several capabilities exist in MR devices to support users' demands and needs [57]. Several scholars discussed these capabilities and features, and among all these features was immersion in MR headsets, as it is one of the most influential aspects of the experience, according to Liberatore and Wagner [58]. Recently, mobility has been considered a prominent feature for several usages in MR applications in different disciplines, encouraging the adoption behaviour [59, 60]. Most immersive technologies and tools require a level of interactivity to be featured in the developed application and it is linked to the static and dynamic content [61]. Several studies claimed the role of interactivity in encouraging users to adopt technologies [62, 63]. Therefore, this study involves these features to investigate their influence on the adoption behaviour of MR devices for CSI training.

a: Perceived Interactivity

Interactivity (PI) refers to the capability of users to modify the structure and substance of a mediated environment instantly [64]. McMillan and Hwang [65] defined interactivity using three key factors: communication direction, user command, and timing. Communication direction pertains to how computers promote human interactions, highlighting bidirectional communication. User control looks into how humans operate computers, with some HCI research concentrating on human awareness and others on computer design [66]. Time, the third aspect of interactivity, assesses how swiftly and effortlessly users can move within an application. Interactive systems allow users to operate at their pace and select their desired navigation routes [67]. In previous studies that adopted AR and VR, CSI training systems adopted interactivity which is considered an integral part of the training [13, 68]. This is due to the need to get responses from virtual crime scenes, collect evidence, and validate the investigation [14]. Papakostas, et al. [62] argued that the perceived interactivity of an AR training system positively impacted trainees' ease of using the system. Another study conducted by Pantano, et al. [69] demonstrated that interactivity greatly enhances a consumer's perception of how easy it is to use the AR try-on system for glasses. Moreover, Huang and Liaw [70] claimed that perceived interactivity positively influences the usefulness of using a virtual reality learning system.

Within the scope of this study, the sense of interactivity leads young researchers to have positive perceptions about the utility and user-friendliness of the MR headset and its usage. This subsequently shapes their behavioural intentions in CSI training. By integrating the interactivity of virtual instruments and the captured environment as a foundational factor, we have further developed the model, leading to the formulation of the subsequent hypotheses:

H5. Interactivity has a positive influence on the perceived usefulness of MR in CSI training

H6. Interactivity has a positive influence on the perceived ease of use of MR in CSI training.

b: Perceived Immersion

Immersion (IM) is a complex concept with multiple interpretations across academic literature. Scholars discussed its various conceptualisations, from being a characteristic of the VR system itself to the perceptual and narrative responses elicited within a virtual environment [71]. In contrast, other scholars see immersion as an objective property that can be measured, which conflicts with the perspective of immersion as an individual's personal psychological experience [72]. Slater and Sanchez-Vives [72] define immersion as a quantifiable feature of a VR system, indicating that a system is more immersive when it can replicate the characteristics of another system. For instance, a VR system using a head-mounted display can fully mimic the functionalities of a desktop VR system, but the opposite isn't feasible. While Slater and Sanchez-Vives [72] interpretation of immersion sheds light on the immersion potential of VR devices, it doesn't necessarily address the users' sensory experiences or how they interact with virtual content, which Mütterlein [73] views as a subjective evaluation of immersion. Such diverse perspectives highlight the multifaceted nature of immersion. It can be seen as a technological trait, a purely physical feeling similar to being submerged in a substance like water, or an entirely mental engagement, much like immersion in an exciting novel [74, 75].

Disztinger, et al. [76] described the perceived immersion as a person's ability to fully engage in a virtual setting. Immersion is considered a critical component of VR [77]. The spectrum of VR immersion, ranging from low to high, was theorised by Milgram and Kishino [78] in 1994 and later by Kim and Leathem [79] in 2018. Based on this taxonomy, as users engage with more advanced VR systems on the spectrum, they would increasingly feel as though they are experiencing an unmediated reality, which is considered a mixed reality in this study [14, 80]. The sense of immersion makes users in immersive environments operate more efficiently and feel a stronger sense of presence compared to those in non-immersive environments [81]. Kothgassner, et al. [82] highlighted that the more immersive a VR experience is, the more it is accepted by users. The sense of being present in the virtual environments - representing crime scenes in this study- during a VR experience evokes strong feelings in the participants' minds. Huang, et al. [83] found a meaningful and positive relationship between immersion and perceived usefulness, though they did not observe a significant link with perceived ease of use. Explaining this pattern of immersion, they pointed out that the VR equipment used in their research wasn't genuinely immersive VR and that users could only interact with the system through simple tasks like zooming and rotating a 3D object. There haven't been any recognised studies using structural equation modelling that have examined the influence of immersion on perceived usefulness or perceived ease of use for a high-immersion HMD-based MR system. When a high-immersion device runs a program with several interactive features, it's possible that immersion could have a notable positive effect on perceived ease of use. A recent article found that perceived immersion has a positive influence on perceived interactivity while using immersive displays, which can be hypothesised in this study with the adoption of mixed reality devices [84]. Consequently, we are proposing the following hypotheses.

H7. Immersion has a positive influence on the perceived ease of use of MR in CSI training

H8. Immersion has a positive influence on the perceived usefulness of MR in CSI training

H9. Immersion has a positive influence on the perceived interactivity of MR in CSI training

c: Mobility

Mobility (MOB) reflects the ability of mobile technology to be used "anywhere" [85]. It describes how users feel they can transition between places and utilise their devices on the go [86]. In regards to this study, it can be defined as "the degree to which users are aware of the spatial environments of crime scenes". Mobile devices excel in giving users a profound feeling of practicality and immediacy, making them believe they can access information swiftly, effortlessly, and promptly [87, 88]. A scholar claims that the accessibility to content and services anywhere-anytime is the most significant feature of mobile-based ICT [89]. Mobility is a core factor in this study, particularly the ability to move around wearing the device and navigate in the virtual space. The significant role of perceived mobility in encouraging the adoption of mobile devices is well documented. Several studies have argued that perceived mobility plays a crucial role in shaping perceived usefulness, which in turn influences user acceptance of mobile systems [88, 90, 91]. It was also argued that perceived mobility influences the perceived ease of use of mobile devices, which can be suggested in this study in the case of MR devices [92]. Based on the VR headset restriction of navigation as it blocks the users' sight, the relationship between mobility and immersion has not been explored. On contrary, mixed reality devices allow users to navigate while wearing the devices as they are transparent. By extension, this study suggests that mobility will be crucial for the adoption of mixed reality wearable devices because their primary utility is to offer quick and direct access to information, leading to the subsequent hypotheses:

H10. Mobility has a positive influence on the perceived usefulness of MR in CSI training.

H11. Mobility has a positive influence on the perceived ease of use of MR in CSI training.

H11. Mobility has a positive influence on the immersion experience of MR in CSI training.

C. TECHNOLOGY ACCEPTANCE MODEL (TAM)

The Technology Acceptance Model (TAM) by Davis [93] is grounded in the psychosocial theories of Reasoned Action by Fishbein and Ajzen [94] and Planned Behavior by Ajzen [95]. These theories aim to clarify and forecast specific behaviours. The initial TAM comprises two external exogenous constructs: the perceived ease of use and the perceived usefulness. Both constructs directly influence the inherent users' behavioural intention to use (BI) technology.

a: Perceived usefulness

Perceived usefulness (PU) was defined as "the degree to which a person believes that using a particular system would enhance his or her job performance" (p.320) [93]. The technology adoption model indicates that the primary motivation for using information technology is its perceived usefulness [96, 97]. Davis [93] argues that if users believe a technology could be beneficial and improve their job performance, their intention to adopt it will increase. Numerous previous studies have shown that perceived usefulness positively impacts the adoption of different technologies, e.g, wearable devices [16, 98], and mobile applications [99, 100]. Several scholars conducted the TAM model to measure the behaviour intention to adopt VR headsets in several contexts and found a significant collection between PU and BI [83, 101, 102]. For the generic training context, PU influences the intention to use VR headsets in higher education training and e-learning for adults [11, 103, 104]. Regarding crime scene investigation training using immersive headsets, a few studies involved TAM to measure the correlation between PU and BI [68], and no study encountered mixed reality devices and their application in this context. Therefore, in view of the previous discussion, this study suggests the following hypothesis:

H13. Perceived usefulness has a positive influence on the behavioural intention to adopt MR in CSI training.

b: Perceived ease of use

The perceived ease of use (PEOU) was defined as "the degree to which a person believes that using a
the particular system would be free of effort" (p.320) [93] and to reduce cognitive efforts [105]. Venkatesh [106] argued that the key behavioural belief influencing user intentions to embrace a particular technology is how easily they perceive it to be used. Cheung, et al. [96] indicate that numerous scholars highlight this as a significant factor in individuals' attitudes toward technology. Furthermore, the perceived simplicity of use is noted to play a crucial role in shaping attitudes [107].
Across various technologies, PEOU showed an influence on the behavioural attention to adopt these technologies. King and He [108] conducted a statistical analysis of 88 studies and found a significant correlation between PEOU and BI in different contexts using recent technologies and applications. During the last two decades, several studies involved TAM

model to explore the user's intention to use VR considering the ease of use construct [101, 109-111]. In the context of CSI training, a scholar conducted VR experience and found a significant relation between PEOU and the adoption of the VR headset to proceed with the training [68]. Despite the general agreement of this correlation between PEOU and BI of adopting VR, mixed reality did not take much attention, especially in the training discipline, particularly in CSI training. In view of the previous discussion, this study suggests the following hypothesis:

H14. Perceived ease of use has a positive influence on the behavioural intention to adopt MR in CSI training.

IV. RESEARCH METHODOLOGY

A. PARTICIPANTS AND PROCEDURE

The study questionnaire was reviewed and evaluated by academics and senior crime scene investigators - see appendix. The data collection was conducted at the Kuwait Police Academy in Kuwait with the help of their staff. The ethical approval has been obtained and approved from the University of Liverpool John Moores. The proposed research model involved the young investigators and the students of the academy to explore the behaviour intention to adopt the MR devices and its applications in CSI training. The questionnaire was constructed from TAM and TTF frameworks, and it is tackled in the following section.

The targeted group of participants are students or young investigators who practice crime investigation in the academy through traditional methods. They were invited by email to attend the trial day. A booking system was prepared to dedicate each participant 20 minutes. The system trail was experimented for several participants for 4 weeks a day after day. Initially, all participants had to sign the consent form then they were instructed to use the device and the mixed reality investigation system. Questionnaire was written initially in English and translated into Arabic (local language in Kuwait). The participant group was provided a training to use the mixed reality system that is comprised of Microsoft HoloLens (MR Headset) and the HoloHolmes application. They were instructed to experiment the investigation mixed reality application in a wide space or an empty classroom. Then, they invited to fill questionnaires, The approximate time for experimenting the mixed reality investigation system took from 15 to 20 min for each participant. Then, questionnaires took additional 5 minutes. Initially, the email sent to 400 students at the final year of the academy. Out of this number, 196 students contributed to the experiment, booked a slot and filled out the survey, leading to a 49% response rate. After removing 36 responses due to incomplete data, 160 valid answers were used for the final analysis.

B. RESEARCH INSTRUMENT

The questionnaire is divided into two essential parts. The first part contains questions that gather demographic details of the respondents. The second part is focused on evaluating eight different constructs, including individual-technology fit (TTF) with 4 items, task-technology fit (ITF) with 3 items, immersion (IM) with 3 items, perceived interactivity (PI) with 3 items, mobility (MOB) with 3 items, perceived ease of use (PEOU) with 4 items, usefulness (PU) with 5 items, and behavioral intention (5 elements). The questionnaire used a five-point Likert scale ranging from 1=strongly disagree to 5=strongly agree. The measurements for individual-technology fit and task-technology fit were adjusted slightly from earlier published work to match this research's focus [21, 112]. The items for mobility were taken from Park, et al. [91], and those for immersion came from Huang, et al. [83]. The criteria for evaluating perceived ease of use, perceived usefulness, and behavioural intention were based on studies by Davis [93] and Chen, et al. [113]. Appendix A provides a detailed demonstration of these constructs and the associated items.

C. MR TRAINING SYSTEM

The study involved designing a mixed reality system that utilises HoloLens 2 for reconstructing crime scenes for junior police officer training. The design is based on the user's workflow, and details for each stage are provided. Tools and development cycle for the mixed reality application rely on Microsoft's HoloLens as a mixed reality device. The process involved the Unity game engine and C# in combination with a mixed reality toolkit (MRTK). Alternative engines like Unreal Engine were considered, but Unity was selected for better support. The application, named HoloHolmes, was deployed through Microsoft Visual Studio. The system includes four stages: "Look Around", "Find Clues", "Check victims" and "Define the criminal" – as depicted in Figure 2.0. After completing the stages, a crime simulation is presented, showing how the incident occurred and the criminal's actions.
Stage 1: Look Around - This stage familiarises the user with the environment and emphasises finding clues through critical examination. A user-guided interface leads the investigation, and the stage includes exploration and interaction through various buttons and interfaces.

- Stage 2: Find Clues- Focused on evidence gathering, this stage employs mixed reality tags to identify and categorise clues. A system of 24 tags is used, divided into different categories. A virtual keyboard allows note-taking and task completion is contingent on proper tagging and checklist completion.

- Stage 3: Check Victims - This stage reveals biometric information of victims and crime tool data through interactive formative tasks. It emulates real-world investigation communication, and completion requires revealing all updated forensic information.

FIGURE 2. **Mixed Reality Application "HoloHolmes"**

- Stage 4: Define the Criminal - Involving identification of the criminal from multiple subjects, this stage offers detailed profiles and additional investigation tools. Unique buttons and visuals aid in suspect scrutiny and decision-making, leading to the identification of the criminal.

- Simulation - This final part emphasises a life-size animation simulation of the entire crime, connecting evidence and actions. The animation provides a replay feature, allowing review and enhanced understanding. Upon solving the case, the user is directed to multiple other missions.

D. APPARATUS

Microsoft HoloLens 2 is a cutting-edge augmented reality device developed by Microsoft and released in 2019. It is an improved version of the original HoloLens and provides enhanced functionalities by integrating new hardware and software technologies [114]. Microsoft HoloLens 2 is a groundbreaking mixed reality (MR) headset designed to enhance collaboration, creativity, and productivity through its augmented reality features. The HoloLens 2 consists of custom-built hardware, including a Holographic Processing Unit (HPU), depth sensors, cameras, and microphones. The combination of these components allows it to create a 3D holographic experience. The device introduces intuitive hand and voice controls, making interactions with virtual objects more natural and engaging [115].

E. DATA ANALYSIS

The data was collected and analysed in IBM SPSS. The analysis adopted the partial least squares structural equation modelling (PLS-SEM) approach through SmartPLS 4.0 to validate the system's usefulness using the TAM. SmartPLS 4.0 was used to test the validity of the hypotheses. In our study, the most crucial statistical methods were made up of two stages, as Hair, et al. [116] recommended this method. The first stage involved conducting the validity of measures, including measure convergence validity and discriminant validity of the measure. The second stage included the examination of the structural model. Defining the sample size in this study depends on the equation provided by Krejcie and Morgan [117] based on population size. Refer to (1) for the sample size calculations, it is considered the probability of $p = 0.05$, meaning there is less than a 5% chance of committing a type I error, or $p < 0.05$.

$$S = \frac{X^2 NP\,(1-P)}{d^2(1-N)+X^2 P\,(1-P)} \quad (1)$$

Here, (S) stands for the necessary sample size, (N) represents the overall population size, (P) denotes the population proportion (presumed to be 0.50 to yield the maximum sample size), (d) indicates the level of accuracy as a proportion (0.05), and (X^2) is the chi-square table value for 1 degree of freedom at the desired confidence level (0.05 equating to 3.841).

V. RESULT AND ANALYSIS

A. RESPONDENTS' PROFILE

Table 1 shows the demographic details of police academy students. The data reveals that 73.75% of the 160 students were male, and their ages varied between 18 and 60 years. The majority of respondents (50%) were between the ages of 26 and 34. More than half of the students, 53.5%, had obtained a bachelor's degree, and 37.50% had never interacted with any devices before the experiment. Out of 160 students said that it would increase their intention to use it if this system could improve their investigative skills.

TABLE I
UNITS FOR MAGNETIC PROPERTIES

Variables Measures		*N*	%
Gender	Male	118	73.7
	Female	42	26.2
Age	18–25	0	0.00
	26–34	80	50.0
	35–45	76	47.5
	46–60	4	2.50
Level of Study	A-LEVEL	27	16.8
	Bachelor	86	53.7
	Masters	37	23.1
	PHD	10	6.25
Which of the following VR devices have you heard about (before the experiment)?	Oculus Quest (1 or 2)	12	7.50
	Samsung VR	36	22.5
	HTC Vive	11	6.87
	HoloLens	41	25.6
	I have not tried any of the above devices	60	37.5
Have you ever used either an AR or a VR headset?	Yes	92	57.5
	No	68	42.5
If this system can improve your investigative skills, will it increase your intention to use it?	Yes	145	90.6
	No	15	9.37

B. Measurement model assessment

The execution of a confirmatory factor analysis (CFA) resulted in the removal of two items, keeping only those with a factor loading greater than 0.05. Consequently, the final model was composed of 29 items, forming the foundation of the confirmatory reflective analysis that was conducted. The findings related to internal consistency reliability and convergent validity are displayed in Table 2.

Both TAM and TTF for CSI training were influenced by other factors related to the behavioural intention to use Mixed Reality devices and applications. Regarding the assessment and measurement of the proposed model, Cronbach's alpha for the reliability coefficient ranged from 0.731 to 0.851, which surpasses the suggested value of 0.7 by Nunnally [118]. Validity is a critical aspect that is significantly required to be measured. Therefore, in Table 2, The Composite Reliability (CR) values fell within the range of 0.713 to 0.899, surpassing the suggested value of 0.70 as per Ab Hamid, et al. [119] and Mitrany [120], thus affirming the reliability of every variable. Validity is assessed by evaluating convergent validity and discriminant validity [121]. Convergent validity was gauged by measuring the average variance extracted (AVE) and factor loadings [122]. As demonstrated in Table 2, all the constructs ranged from 0.586 to 0.711, which is higher than the required value of 0.50, as stated by Hair Jr, et al. [121]. As all the factor loadings of the constructs were beyond the cut-off value of 0.70, the convergent validity was deemed sufficient.

The Fornell-Larker criterion and cross-loadings are used to assess the discriminant validity [123]. According to Table 3, following the Fornell-Larker criterion, the diagonal values (calculated as the square root of AVE) exceed the off-diagonal values in every row and column [124]. These figures indicate a positive correlation coefficient between the constructs. Cross-loading results can be seen in Table 4. The item loadings related to each construct were greater than the content of its corresponding variables. Thus, it can be recommended that there be no doubts about the discriminant validity assessment in this study.

C. STRUCTURAL MODEL ASSESSMENT

In the structure model evaluation, the hypothesis testing was performed through a bootstrapping method of 3,000 re-samples. The hypothesis testing included the standard beta (β), t-values, and p-values, following the guidelines set by Hair Jr, et al. [125]. Prior to the hypothesis testing, an algorithm was developed for the research model, as illustrated in Figure 3.

1) HYPOTHESES OF TTF THEORY

The first four hypotheses are related TTF theory. The findings as depicted in Table 4 and Figure 4 showed that TTF has a significant positive influence on PU ($\beta = 0.326$, $t = 2.885$), while TTF has no significant influence on PEOU ($\beta = 0.099$, $t = 1.089$). As a result, H1 was accepted and H2 was rejected. Additionally, the findings revealed that ITF has no significant influence on PU ($\beta = -0.008$, $t = 0.065$) and ITF has a significant positive influence on PEOU ($\beta = 0.325$, $t = 3.662$). Therefore, H3 was rejected, while H4 was accepted. These results are consistent with previous studies [21] [126] [127] [128] [129] [130].

TABLE 2
CONVERGENT VALIDITY RESULTS

Construct	Items	Factor loadings	Cronbach's Alpha	CR	AVE
BI	BI1	0.794	0.826	0.882	0.653
	BI2	0.741			
	BI4	0.818			
	BI5	0.873			
IM	IM1	0.786	0.738	0.817	0.691
	IM2	0.874			
	IM3	0.789			
ITF	ITF1	0.833	0.741	0.809	0.586
	ITF2	0.729			
	ITF3	0.730			
MOB	MOB1	0.864	0.790	0.831	0.711
	MOB2	0.825			
	MOB3	0.822			
PEOU	PEOU1	0.823	0.851	0.894	0.629
	PEOU2	0.768			
	PEOU3	0.816			
	PEOU4	0.816			
	PEOU5	0.738			
PI	PI1	0.751	0.731	0.813	0.686
	PI2	0.899			
	PI3	0.835			
PU	PU1	0.821	0.805	0.870	0.627
	PU3	0.811			
	PU4	0.793			
	PU5	0.739			
TTF	TTF1	0.734	0.789	0.863	0.613
	TTF2	0.852			
	TTF3	0.824			
	TTF4	0.713			

TABLE 3.
FORNELL–LARKER CRITERION

	BI	IM	ITF	MOB	PEOU	PI	PU	TTF
BI	**0.808**							
IM	0.511	**0.831**						
ITF	0.601	0.528	**0.765**					
MOB	0.446	0.413	0.551	**0.843**				
PEOU	0.683	0.461	0.656	0.536	**0.793**			
PI	0.561	0.513	0.577	0.574	0.605	**0.828**		
PU	0.594	0.508	0.53	0.517	0.651	0.455	**0.792**	
TTF	0.613	0.469	0.762	0.385	0.552	0.487	0.545	**0.783**

TABLE 4.
CROSS LOADINGS

	BI	IM	ITF	MOB	PEOU	PI	PU	TTF
BI1	**0.794**	0.440	0.549	0.411	0.498	0.389	0.496	0.493
BI2	**0.741**	0.364	0.448	0.373	0.426	0.373	0.384	0.457
BI4	**0.818**	0.409	0.51	0.304	0.66	0.496	0.572	0.560
BI5	**0.873**	0.437	0.433	0.376	0.578	0.531	0.437	0.459
IM1	0.323	**0.786**	0.411	0.273	0.359	0.310	0.427	0.420
IM2	0.509	**0.874**	0.464	0.402	0.405	0.521	0.421	0.369
IM3	0.521	**0.789**	0.398	0.462	0.543	0.455	0.387	0.414
ITF1	0.542	0.456	**0.833**	0.487	0.543	0.446	0.418	0.621
ITF2	0.401	0.473	**0.729**	0.465	0.467	0.538	0.429	0.477
ITF3	0.430	0.277	**0.730**	0.307	0.495	0.339	0.370	0.651
MOB1	0.369	0.327	0.471	**0.864**	0.481	0.562	0.494	0.414
MOB2	0.420	0.411	0.423	**0.825**	0.593	0.429	0.382	0.477
MOB3	0.386	0.374	0.459	**0.822**	0.420	0.396	0.372	0.224
PEOU1	0.561	0.370	0.478	0.473	**0.823**	0.538	0.460	0.389
PEOU2	0.555	0.409	0.585	0.376	**0.768**	0.449	0.513	0.460
PEOU3	0.565	0.324	0.577	0.416	**0.816**	0.469	0.563	0.515
PEOU4	0.544	0.352	0.537	0.534	**0.816**	0.495	0.509	0.424
PEOU5	0.473	0.376	0.410	0.309	**0.738**	0.445	0.543	0.393
PI1	0.374	0.309	0.539	0.415	0.435	**0.751**	0.255	0.434
PI2	0.536	0.512	0.449	0.527	0.556	**0.899**	0.466	0.393
PI3	0.574	0.366	0.431	0.432	0.502	**0.835**	0.412	0.366
PU1	0.482	0.305	0.447	0.395	0.558	0.411	**0.821**	0.484
PU3	0.480	0.378	0.394	0.356	0.536	0.440	**0.811**	0.460
PU4	0.489	0.498	0.452	0.478	0.534	0.379	**0.793**	0.395
PU5	0.425	0.422	0.382	0.405	0.429	0.201	**0.739**	0.387
TTF1	0.430	0.315	0.561	0.224	0.406	0.362	0.405	**0.734**
TTF2	0.544	0.437	0.624	0.294	0.429	0.307	0.425	**0.852**
TTF3	0.509	0.374	0.611	0.420	0.543	0.537	0.478	**0.824**
TTF4	0.429	0.340	0.596	0.236	0.314	0.278	0.390	**0.713**

2) HYPOTHESES OF TAM THEORY

The second set of ten hypotheses is related to the TAM model. As depicted in Table 5 and Figure 4, The results similarly showed that the PI's influence on PU is insignificant (β = 0.022, t = 0.022), while its influence on PEOU is significant (β = 0.252, t = 2.743). Consequently, H5 was rejected, and H6 was accepted. These results are consistent with the previous studies [70] [131] [132]. Moreover, the study revealed that IM significantly influences PU (β = 0.229, t = 0.229), but has an insignificant effect on PEOU (β = 0.051, t = 0.051), leading to the acceptance of H7 and rejection of H8. However, It was revealed that IM significantly influences PI ((β = 0.515, t = 9.631), leading to the acceptance of H9. These results are consistent with previous studies [83] [133] [134] [76]. Additionally, the findings illustrated that MOB significantly impacts both PU (β = 0.289, t = 3.610) and PEOU (β = 0.157, t = 2.276), resulting in the acceptance of H9 and H10. The study also indicated that IM significantly influences PI (β = 0.515, t = 9.631), hence H11 was accepted, and MOB has a significant effect on IM (β = 0.418, t = 5.614), so H12 was accepted as well. These results are consistent with previous studies [88] [135] [136] [137] [138]. Lastly, the study proved that both PU (β = 0.265, t = 3.571) and PEOU (β = 0.512, t = 7.631) have a significant influence on BI, leading to the acceptance of H13 and H14. These results are consistent with previous studies [21] [139] [103] [128] [129] [130].

TABLE 5.
HYPOTHESES TESTING RESULTS

H	Independent	Relationship	Independent	Std. Beta	t-value	p-value	Result
H1	TTF	⟶	PU	0.326	2.885	0.004*	Supported
H2	TTF	⟶	PEOU	0.099	1.089	0.276	Rejected
H3	ITF	⟶	PU	-0.008	0.065	0.949	Rejected
H4	ITF	⟶	PEOU	0.325	3.662	0.000*	Supported
H5	PI	⟶	PU	0.022	0.188	0.851	Rejected
H6	PI	⟶	PEOU	0.252	2.743	0.006*	Supported
H7	IM	⟶	PU	0.229	2.888	0.004*	Supported
H8	IM	⟶	PEOU	0.051	0.657	0.511	Rejected
H9	IM	⟶	PI	0.515	9.631	0.000*	Supported
H10	MOB	⟶	PU	0.289	3.610	0.000*	Supported
H11	MOB	⟶	PEOU	0.157	2.276	0.023*	Supported
H12	MOB	⟶	IM	0.418	5.614	0.000*	Supported
H13	PU	⟶	BI	0.265	3.571	0.000*	Supported
H14	PEOU	⟶	BI	0.512	7.631	0.000*	Supported

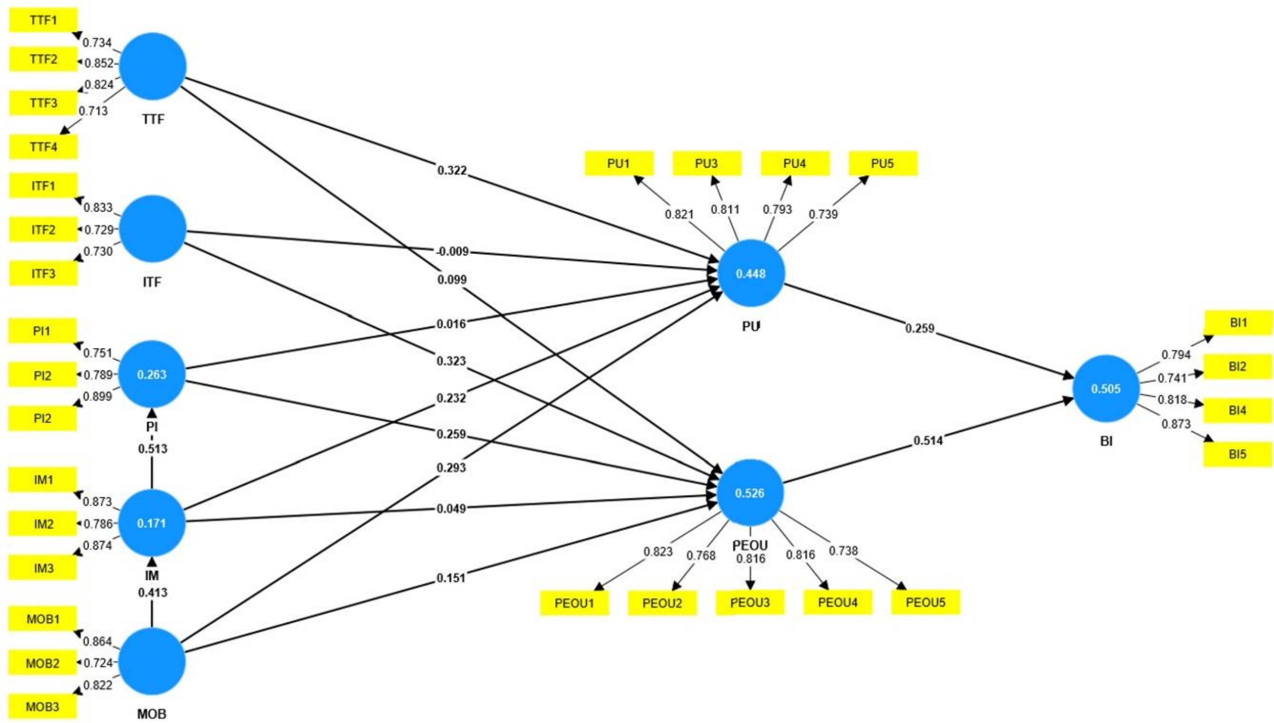

FIGURE 3. **PLS-SEM Algorithm Model Results**

Regarding the R2 results, according to Figure 3, it was noticed that task technology fit and individual technology fit, perceived interaction, perceived immersion, and perceived mobility together explain 52.6% of the variance in perceived ease of use. Interestingly, both perceived ease of use and perceived usefulness explain 50.5% of the variance in behaviour intention to adopt mixed reality devices and their application in CSI training. Considering the R2 threshold values, the R2 values resulting from this proposed model are considered acceptable.

VI. DISCUSSION AND IMPLICATIONS

The word "data" is plural, not singular. The advancement of mixed reality technologies offers unparalleled prospects for police students and young investigators by facilitating the accessibility to crime scenes in a virtual format and conducting investigation training. This technology allows investigation in remote collaboration with the visual and auditory communication capability between investigators and trainees [140]. Traditional CSI training often relies on static, pre-designed settings that might not account for the varied nature

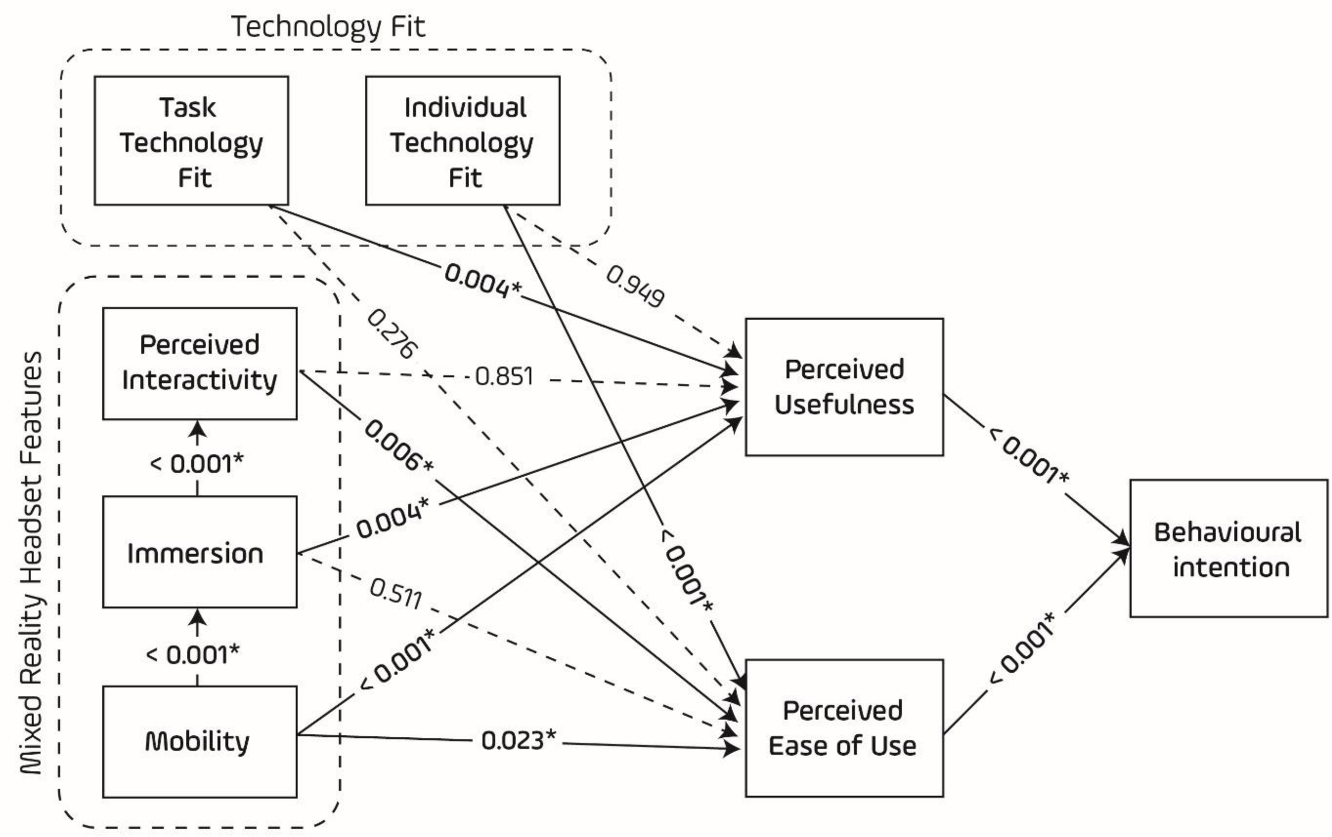

FIGURE 4. **The Measured Framework**

of crime scenes. However, MR can create dynamic, evolving scenarios that are adaptable in real time. However, there is limited understanding regarding the utilisation of these devices in the CSI training context [7]. Consequently, the present study aims to investigate specific factors anticipated to influence police students' willingness to adopt these technologies for CSI training purposes. To this end, a novel theoretical framework is introduced, which enhances the TAM by incorporating TTF variables and key attributes of mixed reality devices, specifically their mobility, immersion and interactivity.

The findings of the current investigation confirm that TTF significantly influences Perceived Usefulness (PU), suggesting that users assessed the HoloHolmes Mixed Reality application to be an effective instrument for crime scene investigation in their routine training and practices. The utility and pertinence of technology for particular tasks are key determinants in its adoption and practical use in varying crime scene training scenarios, as highlighted by Mayne and Green [7]. Several previous studies confirmed the positive and significant influence of TTF on PU in several contexts [21] [126] [127] [128] [129] [130]. Contrary to these findings, a prior study conducted by Vanduhe, et al. [103] did not present conclusive evidence to affirm or negate a significant influence of TTF on PU, although a positive association between the two variables was observed. The significant relationship between Technology Task Fit and perceived usefulness suggests that when the technology closely aligns with the operational needs of crime scene investigation, it is more likely to be viewed as beneficial. This emphasizes the importance of co-design approaches, wherein law enforcement professionals are involved in the iterative design process of the MR application. Future research may explore the granularity of this alignment; for instance, whether more advanced features like real-time data analysis or collaborative interfaces have varying degrees of perceived usefulness.

The present research results indicated that Task-Technology Fit (TTF) does not significantly influence Perceived Ease of Use (PEOU), thereby leading to rejecting the hypothesised relationship between TTF and PEOU. On the other hand, a positive correlation between TTF and PEOU was observed. This observation is congruent with a previous study, which was particularly undertaken by Yen, et al. [139] and Ishfaq and Mengxing [141] to explore the adoption of different technologies. Both literature studies rejected the relationship between TTF and PEOU, leading to dismissing the posited linkage between these variables. In regard to the context of this study, when mixed reality technology is viewed as compatible with a given task or exhibits Task-Technology Fit (TTF), it will not influence enhancing Perceived Ease of Use of the MR devices and their applications. One hypothesis for further inquiry could be that the technical complexities introduced by a well-fitting technology are perhaps offset by its perceived benefit, rendering the ease of use as a secondary consideration. The results of this study, which the police academy students conducted, revealed that the influence of ITF on PU was insignificant, thereby rejecting the hypothesised relationship between the two variables. These results aligned with earlier studies that adopted different technologies in different contexts and argued that ITF has an insignificant impact on PU, leading to rejecting the hypothesised association [21] [130]. In a different context, authors claimed that ITF alone may not be adequate to achieve the degree of PU necessary for a technology's broad acceptance [21]. Conversely, in this investigation, ITF significantly impacted PEOU, which accordingly accepts the tested relationship between ITF and PEOU. This result goes along with the previous literature that utilised different technologies [21] [129] [130]. On the other hand, this outcome contradicts a previous study, which proved that ITF has no significant influence on PEOU, resulting in rejecting the explored correlation [142]. For the context of mixed reality and its applications, despite the new user experience that students were exposed to, this result highlights an absence of a positive correlation and suggests that ITF does not significantly influence PEOU [142]. The insignificant relationship between Individual Task Fit and perceived usefulness might indicate that personal proficiency or suitability for crime scene investigation tasks doesn't strongly influence how useful the technology is perceived to be. However, its significant influence on perceived ease of use suggests that prior expertise in crime scene investigations can potentially make the MR interface more intuitive to navigate.

Regarding the perceived interaction for the MR application, the findings suggest that PI has no significant influence on Perceived Usefulness (PU), confirming the rejection of the hypothesised correlation between PI and PU. There is a lack of uniform agreement within the extant scholarship concerning the degree to which PI significantly affects PU. The multifaceted nature of interactivity, especially in the realm of AR/VR technologies, may contribute to ambiguities surrounding its perceived usefulness [143]. On the contrary, the results proved that the perceived interactivity of the MR device and its application significantly influence the perceived ease of use; hence, the measured relationship between PI and PEOU is accepted. This aligns with prior research findings that have confirmed the substantial influence of PEOU on PI, thereby confirming the posited link between PI and PEOU [132] [70]. Consequently, the study establishes a unidirectional dependency, indicating that PEOU is a determinant of PI rather than vice versa [144]. While perceived interactivity did not significantly influence perceived usefulness, its notable impact on perceived ease of use calls for further investigation. This might imply that a higher degree of interactivity does not necessarily translate into functional advantage but does contribute to a more intuitive or engaging user experience.

Regarding the immersion construct, the findings substantiate a significant influence of Immersion (IM) on Perceived Usefulness (PU), thereby confirming the hypothesised relationship between the IM and PU. Contrarily, the prior literature lacks a comprehensive understanding of the influence of IM on PU in the discipline of training using AR/VR devices; however, there are few in different disciplines [83] [133]. The concept of immersion presents a complicated variable that challenges the measurement of any direct relationship with Perceived Usefulness (PU), leading to the rejection of the measured relationship between IM and PU in the existing literature. In the current investigation, it was observed that immersion (IM) has no significant impact on the Perceived Ease of Use (PEOU), leading to the rejection of the hypothesised relationship between IM and PEOU. These results align with previous studies that confirmed the insignificance of the impact of IM on PEOU [83] [145]. Furthermore, there was no evidence from existing literature to validate a significant influence of IM on PEOU, particularly in the training discipline using mixed reality devices. Conversely, prior research that Ghobadi, et al. [146] conducted identified a robust connection between IM and PEOU, inferring that high levels of immersion facilitated users in adopting new technology, thereby enhancing PEOU. In conditions of heightened immersion, technology is perceived as user-friendly and contextually pertinent, underscoring the potential significance of immersion in shaping ease of use. Ghobadi, et al. [146] also reported a robust positive interrelation between IM and PEOU, evidencing direct positive correlations between IM and PEOU.

This study also found that IM has a positive significant influence on PI, thereby confirming the hypothesised relationship between IM and PI. Surprisingly, there was no prior study that can either confirm or reject this relationship. These results imply that technologies involving AR, VR or MR have the potential to positively shape the way users perceive interactivity, thereby augmenting their learning experience in new technological environments. Therefore, the degree of immersion is crucial for affecting how users perceive a technology's interactive capabilities, which consequently impacts the technology's utilisation and adoption rate. If technology provides an experience that is both deeply immersive and meets the needs of the user, it is more likely to experience higher rates of adoption and usage [147]. Immersion's significant impact on perceived usefulness and interactivity, but not on ease of use, could be explained by the role it plays in replicating a 'real-world' training environment. This raises important questions about the optimal level of immersion required for effective training, which merits further empirical study.

In regards to mobility, the findings of this investigation confirmed that MOB has a significant influence on PU, thereby accepting the hypothesised relationship between MOB and PU. The existing academic literature lacks definitive insights into the influence of MOB on PU in the discipline of training using mixed reality devices, despite a few establishing this relationship with different technologies in different domains [88] [135]. Mobile technologies may necessitate sacrifices in certain domains, and demand increased effort for effective utilization. Consequently, despite its potential contributions in realms such as criminal investigation, mobility poses a disadvantage to PU, according to existing scholarly work. This accentuates the notion that mobility should not be a prioritized factor or subject of focus [148]. Furthermore, this research confirmed that MOB significantly influences PEOU, thereby accepting the hypothesised relationship between MOB and PEOU. Previous literature proved the relationship between MOB and PEOU with different technologies [136] [137] [138]. For the current study, mobility is crucial for young police investigators to walk around the scanned crime scene to conduct the investigation practices. Hence, these findings confirm that the mobility feature of the mixed reality devices influences the perceived usefulness and the ease of use of the MR application, and facilitates understanding of the application and establishes a friendly user experience.

The outcomes of this study indicate a significant influence of MOB on IM, thus confirming the examined correlation between MOB and IM. Despite the lack of previous studies regarding this type of relationship, the mobility privilege in mixed reality devices in this study proved the enhancement of the perceived interactivity between the user and the virtual content. This reflects on the nature of practising the investigation of the crime scene by the young investigators that is performed in this study. Mobility influencing both perceived usefulness and ease of use is significant, especially in the context of crime scene investigations, which often require rapid response and adaptability. This stresses the need for future MR applications to focus on lightweight, mobile solutions without compromising on computational power.

In the present research, and in line with prior literature, it was indicated that Perceived Usefulness (PU) significantly influences Behavioural Intention (BI); as such, the hypothesised relationship between PU and BI is accepted. PU was identified as a key determinant of BI, specifically within the context of student engagement with e-portfolios. Hence, PU serves as a crucial factor in shaping BI [149]. Although several studies confirmed this relationship in several types of technologies [139] [103] [21] [129] [130], none of the published literature involved mixed reality and its application to measure this relationship. Moreover, the current study demonstrates that Perceived Ease of Use (PEOU) also significantly influences BI, confirming the hypothesis that the relationship between PEOU and BI is significant. These results were aligned with prior research, which emphasised the significant influence of PEOU on BI [139] [103] [128] [129]. Therefore, it becomes imperative for emerging technologies to be conceived as user-friendly in order to foster user acceptance and adoption. When a technological tool is viewed as user-friendly, it minimises obstacles to its application, thereby enhancing its significance for users in accomplishing their tasks. As a result, this increases the likelihood of technology adoption. The intent to employ the technology and its actual behaviour are essential elements to examine in user acceptance [150]. Both perceived usefulness and ease of use were found to significantly affect the behavioural intention to adopt the MR system. This indicates that for widespread adoption, MR applications must not only be functionally aligned with the task but also be easy to interact with.

VII. CONCLUSION AND FUTURE WORK

A. THEORETICAL CONTRIBUTIONS

In conclusion, this study successfully developed a systematic MR application using Microsoft HoloLens 2 to enhance communication and interaction among investigators during crime scene investigations. The research incorporated five external factors from the Technology Acceptance Model (TAM) and utilised a mixed-methods approach. The quantitative phase employed SmartPLS 4.0 and structural equation modelling to analyse the relationships between the research model's constructs.

In light of the empirical results and further discussion, it is evident that Mixed Reality (MR) applications using HoloLens hold significant potential for building effective training systems in crime scene investigation for police students. However, the adoption and success of such technology are influenced by a complex interplay of variables such as Technology Task Fit, Individual Task Fit, Perceived Interaction, Immersion, Mobility, Perceived Usefulness, and Perceived Ease of Use.

The observed significant influence of Technology Task Fit on perceived usefulness underscores the critical role that technological alignment plays in addressing the operational needs of crime scene investigation. Meanwhile, Individual Task Fit's significant influence on perceived ease of use indicates that the interface becomes more intuitive with prior expertise in the field, emphasizing the importance of user-centric design. The data reveals that both perceived usefulness and ease of use significantly affect the behavioural intention to adopt the MR system. As it was insightfully pointed out, the development of MR applications should be directed toward creating a balance between functionality and user experience. Future research should focus on specific elements, such as real-time data analysis and collaborative interfaces, which can enhance both the perceived usefulness and ease of use of these systems.

The findings of this research not only provide valuable insights for the development and evaluation of MR applications in law enforcement training but also contribute to the broader discourse on the adoption of advanced technology in professional educational contexts.

The multi-dimensional relationships between these factors offer numerous avenues for future research. Particular attention should be given to studying the long-term impacts of such technology in real-world law enforcement training. Moreover, these insights could serve as a foundational framework for developing and evaluating similar MR-based training systems in various professional settings.

B. PRACTICAL CONTRIBUTIONS

The practical contributions of this study lie in the development and implementation of the MR application itself. The application's realistic environment allows investigators to experience crime scenes more effectively, aiding in evidence collection and navigation. This has the potential to improve the efficiency and accuracy of crime scene investigations, leading to more reliable and comprehensive outcomes. Furthermore, the application's use in court settings can enhance judges' and juries' understanding of the crime scene, leading to informed decision-making and potentially reducing the time required for trial processes.

C. LIMITATIONS AND FUTURE WORK

Concerning the limitations, the sample size and demographic distribution of the participants might be one of the study limitations. If the study primarily focused on a specific group, the results might not be generalizable to a larger, more diverse population. Another limitation is relying on one type of mixed reality device; The study is tailored to HoloLens and its capabilities. The findings can be expanded to other MR platforms or evolving technologies. Furthermore, the study is specifically focused on crime scene investigation for police students. The findings might not apply to other training domains within or outside law enforcement.

Future research could involve larger and more diverse genders to validate the study's findings across various populations. It would be beneficial to compare the effectiveness of HoloLens with other MR or Virtual Reality (VR) platforms to determine any platform-specific advantages or limitations. Future studies could employ objective measures such as task completion time, error rates, or physiological indicators like eye tracking to supplement subjective self-reports. Research could explore the applicability of these MR technologies in different law enforcement or educational contexts, beyond crime scene investigation. Additionally, further studies could be designed to assess how organizational and policy-level factors influence the adoption and scaling of MR technologies in professional training environments.

APPENDIX A

Technology Acceptance Model (TAM) Questionnaire

Task-Technology Fit	
TTF1	The mixed reality application can fit the requirement of practising crime scene investigation.
TTF2	Using the mixed reality application fits with my educational practice.
TTF3	While practising, it is easy to understand which function to use on the mixed reality crime scene application.
TTF4	The mixed reality application is suitable for helping me to complete my crime scene investigation education.
Individual-Technology Fit	
ITF1	I can independently and consciously practice crime scene investigation on the mixed reality application.
ITF2	I can participate in various types of discussions and evaluations on the mixed reality application.
ITF3	I can solve crime cases and get good marks for outstanding performance on the mixed reality app.
Immersion	
IM1	The application provides an authentic crime scene for learning and practice.
IM2	The app created an environment that immerses users into a virtual crime scene investigation despite being physically inside a classroom.
IM3	I feel fully engaged by the mixed reality crime scene environment.
Perceived Interactivity	
PI1	I felt that I had a lot of control over my Investigation practices of using the MR application.
PI2	Getting information from the MR application was very fast.
PI3	I think using the MR application was enjoyable.
Mobility	
MOB1	Mobility is an outstanding advantage of the MR application.
MOB2	I feel that I can use the MR application anywhere at any time.
MOB3	Mobility makes it possible to get the required information on time.
Perceived Ease of Use	
PU1	I believe that the HoloLens application would be useful for practising crime scene investigation practices.
PU2	Using the MR application in HoloLens increases my learning and practice achievement.
PU3	Using the HoloLens app makes it easier for me to better understand the investigation practices in crime scenes.
PU4	I think the HoloLens app can help me perform the required investigation practices in crime cases.
PU5	Overall, using the HoloLens application in crime investigation learning and practices is useful.

Perceived Usefulness	
PU1	I believe that the HoloLens application would be useful for practising crime scene investigation practices.
PU2	Using the MR application in HoloLens increases my learning and practice achievement.
PU3	Using the HoloLens app makes it easier for me to better understand the investigation practices in crime scenes.
PU4	I think the HoloLens app can help me perform the required investigation practices in crime cases.
PU5	Overall, using the HoloLens application in crime investigation learning and practices is useful.
Behavioural intention	
BI1	I intend to start using the HoloLens crime scene app to interact with my colleagues and lecturers.
BI2	I intend to continue using the HoloLens crime scene app frequently.
BI3	I will strongly recommend the use of mixed reality crime scene app to my peers.
BI4	I will always try to use the HoloLens application in my practical studies on a daily basis.
BI5	Overall, I intend to continue using the crime scene application in my future learning.

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REFERENCES

[1] J. T. Fish, L. S. Miller, M. C. Braswell, and E. W. Wallace, *Crime scene investigation*. Routledge, 2013.
[2] B. Wassom, *Augmented reality law, privacy, and ethics: Law, society, and emerging AR technologies*. Syngress, 2014.
[3] S. Greengard, *Virtual reality*. Mit Press, 2019.
[4] R. E. Ioimo, *Applying the theory of task technology fit in assessing police use of field mobile computing*. Nova Southeastern University, 2000.
[5] V. Bulgakov, I. Trushchenkov, and E. Bulgakova, "Spherical panoramic photo shooting and virtual reality demonstration of a crime scene," in *Conference on Creativity in Intelligent Technologies and Data Science*, 2019: Springer, pp. 217-225.
[6] C. Jacobs, *Interactive panoramas: techniques for digital panoramic photography*. Springer Science & Business Media, 2004.
[7] R. Mayne and H. Green, "Virtual reality for teaching and learning in crime scene investigation," *Science & Justice,* vol. 60, no. 5, pp. 466-472, 2020.
[8] M. Mentzelopoulos, J. Parrish, P. Kathrani, and D. Economou, "REVRLaw: An immersive way for teaching criminal law using virtual reality," in *International Conference on Immersive Learning*, 2016: Springer, pp. 73-84.
[9] U. Karabiyik, C. Mousas, D. Sirota, T. Iwai, and M. Akdere, "A virtual reality framework for training incident first responders and digital forensic investigators," in *International Symposium on Visual Computing*, 2019: Springer, pp. 469-480.
[10] M. Zhang, L. Shu, X. Luo, M. Yuan, and X. Zheng, "Virtual reality technology in construction safety training: Extended technology acceptance model," *Automation in Construction,* vol. 135, p. 104113, 2022.
[11] J. Iqbal and M. S. Sidhu, "Acceptance of dance training system based on augmented reality and technology acceptance model (TAM)," *Virtual Reality,* vol. 26, no. 1, pp. 33-54, 2022.
[12] S. G. Fussell and D. Truong, "Using virtual reality for dynamic learning: an extended technology acceptance model," *Virtual Reality,* vol. 26, no. 1, pp. 249-267, 2022.
[13] S. Lukosch, R. Poelman, O. Akman, and P. Jonker, "A novel gesture-based interface for crime scene investigation in mediated reality," in *Proceedings of the CSCW workshop on Exploring collaboration in challenging environments, February*, 2012.
[14] G. Makransky and L. Lilleholt, "A structural equation modeling investigation of the emotional value of immersive virtual reality in education," *Educational Technology Research and Development,* vol. 66, no. 5, pp. 1141-1164, 2018.
[15] K. J. Kim and D.-H. Shin, "An acceptance model for smart watches: Implications for the adoption of future wearable technology," *Internet Research,* vol. 25, no. 4, pp. 527-541, 2015.
[16] M. Al-Emran, R. Al-Maroof, M. A. Al-Sharafi, and I. Arpaci, "What impacts learning with wearables? An integrated theoretical model," *Interactive learning environments,* vol. 30, no. 10, pp. 1897-1917, 2022.
[17] A. Cheng, D. Ma, Y. Pan, and H. Qian, "Enhancing Museum Visiting Experience: Investigating the Relationships Between Augmented Reality Quality, Immersion, and TAM Using PLS-SEM," *International Journal of Human–Computer Interaction,* pp. 1-12, 2023.
[18] D. Hidayat, C. Pangaribuan, O. Putra, and F. Taufiq, "Expanding the technology acceptance model with the inclusion of trust and mobility to assess e-wallet user behavior: Evidence from OVO consumers in Indonesia," in *IOP Conference Series: Earth and Environmental Science*, 2021, vol. 729, no. 1: IOP Publishing, p. 012050.
[19] N. Chung, H. Lee, J.-Y. Kim, and C. Koo, "The role of augmented reality for experience-influenced environments: The case of cultural heritage tourism in Korea," *Journal of Travel Research,* vol. 57, no. 5, pp. 627-643, 2018.
[20] D. Pal and S. Patra, "University students' perception of video-based learning in times of COVID-19: A TAM/TTF perspective," *International Journal of Human–Computer Interaction,* vol. 37, no. 10, pp. 903-921, 2021.
[21] B. Wu and X. Chen, "Continuance intention to use MOOCs: Integrating the technology acceptance model (TAM) and task technology fit (TTF) model," *Computers in human behavior,* vol. 67, pp. 221-232, 2017.
[22] A. Lo Presti, A. De Rosa, and E. Viceconte, "I want to learn more! Integrating technology acceptance and task–technology fit models for predicting behavioural and future learning intentions," *Journal of Workplace Learning,* vol. 33, no. 8, pp. 591-605, 2021.
[23] Z. Z. Ariffin, K. T. Heng, A. Y. Yaakop, N. F. Mokhtar, and N. Mahadi, "Conceptualizing gen y online shopping behaviour: integrating task-technology fit (TTF) model and extended technology acceptance model (TAM)," *PROCEEDING OF ICARBSS 2017 LANGKAWI, MALAYSIA,* vol. 2017, no. 29th, p. 330, 2017.
[24] Q. Al-Maatouk, M. S. Othman, A. Aldraiweesh, U. Alturki, W. M. Al-Rahmi, and A. A. Aljeraiwi, "Task-technology fit and technology acceptance model application to structure and evaluate the adoption of social media in academia," *IEEE Access,* vol. 8, pp. 78427-78440, 2020.
[25] T. L. Lim and A. S. H. Lee, "Extended TAM and TTF Model: A Framework for the 21 st Century Teaching and Learning," in *2021*

International Conference on Computer & Information Sciences (ICCOINS), 2021: IEEE, pp. 339-334.

[26] B. A. Fisher, *Ethics in the crime laboratory and in crime scene investigations*. Academic Press Oxford, 2012.

[27] S. N. Kader, W. B. Ng, S. W. L. Tan, and F. M. Fung, "Building an interactive immersive virtual reality crime scene for future chemists to learn forensic science chemistry," *Journal of Chemical Education,* vol. 97, no. 9, pp. 2651-2656, 2020.

[28] J. Mennell, "The future of forensic and crime scene science: Part II. A UK perspective on forensic science education," *Forensic science international,* vol. 157, pp. S13-S20, 2006.

[29] R. Spain *et al.*, "Me and My VE, Part 5: Applications in Human Factors Research and Practice," in *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 2018, vol. 62, no. 1: SAGE Publications Sage CA: Los Angeles, CA, pp. 2051-2055.

[30] T. Teo, G. A. Lee, M. Billinghurst, and M. Adcock, "360Drops: Mixed Reality Remote Collaboration using 360 Panoramas within the 3D Scene," in *SIGGRAPH Asia 2019 Emerging Technologies*, 2019, pp. 1-2.

[31] L. M. Rühmann, M. Prilla, and G. Brown, "Cooperative mixed reality: an analysis tool," in *Proceedings of the 2018 ACM Conference on Supporting Groupwork*, 2018, pp. 107-111.

[32] D. Datcu, S. G. Lukosch, and H. K. Lukosch, "Handheld augmented reality for distributed collaborative crime scene investigation," in *Proceedings of the 19th International Conference on Supporting Group Work*, 2016, pp. 267-276.

[33] R. Poelman, O. Akman, S. Lukosch, and P. Jonker, "As if being there: mediated reality for crime scene investigation," in *Proceedings of the ACM 2012 conference on computer supported cooperative work*, 2012, pp. 1267-1276.

[34] K. Sandvik, "Crime Scenes as Augmented Reality: Models for Enhancing Places Emotionally by Means of Narratives, Fictions and Virtual Reality," *Re-Investing Authenticity. Tourism, Place and Emotions,* pp. 138-153, 2010.

[35] M. Speicher, B. D. Hall, and M. Nebeling, "What is mixed reality?," in *Proceedings of the 2019 CHI conference on human factors in computing systems*, 2019, pp. 1-15.

[36] W. S. Leung and F. F. Blauw, "An augmented reality approach to delivering a connected digital forensics training experience," in *Information Science and Applications*: Springer, 2020, pp. 353-361.

[37] V. Tolstolutsky, G. Kuzenkova, and V. Malichenko, "The Experience of Using Augmented Reality in the Reconstruction of the Crime Scene Committed in Transport," in *International Scientific Siberian Transport Forum*, 2021: Springer, pp. 1095-1102.

[38] H. Engelbrecht and S. G. Lukosch, "Viability of augmented content for field policing," in *2018 IEEE International Symposium on Mixed and Augmented Reality Adjunct (ISMAR-Adjunct)*, 2018: IEEE, pp. 386-389.

[39] I. Levstein and L. J. Justice, "Csi4fs®: A markerless augmented reality game–a novel approach to crime scene investigation training," in *Emerging Technologies in Virtual Learning Environments*: IGI Global, 2019, pp. 238-257.

[40] T. Kilgus *et al.*, "Mobile markerless augmented reality and its application in forensic medicine," *International journal of computer assisted radiology and surgery,* vol. 10, no. 5, pp. 573-586, 2015.

[41] B. K. Sharma, R. Bashir, S. A. Philip, and H. Kumar, "A Comparative Study of Mobile Applications for Crime Scene Measurements-A Digital Approach," in *2019 International Conference on Computational Intelligence and Knowledge Economy (ICCIKE)*, 2019: IEEE, pp. 492-495.

[42] S. E. I. Haque and S. Saleem, "Augmented reality based criminal investigation system (arcrime)," in *2020 8th International Symposium on Digital Forensics and Security (ISDFS)*, 2020: IEEE, pp. 1-6.

[43] A. Studio. "Experience compelling new possibilities for storytelling and gameplay when life-sized characters are aware of your presence, share your real space, and interact with you in mixed reality." Microsoft. https://www.asobostudio.com/games/fragments (accessed 21 September, 2022).

[44] J. Cho, T. Jung, K. Macleod, and A. Swenson, "Using virtual reality as a form of simulation in the context of legal education," in *Augmented Reality and Virtual Reality*: Springer, 2021, pp. 141-154.

[45] C.-L. Lee, Y. Fang, Y.-H. Huang, S.-H. Lee, and W. C.-C. Yeh, "Application of wearable devices in crime scene investigation and virtual reality," in *2019 IEEE Symposium Series on Computational Intelligence (SSCI)*, 2019: IEEE, pp. 206-210.

[46] H.-S. Kim, H.-J. Kim, Y.-S. Lee, and J. Lee, "Criminal profiling simulation training and assessment system based on virtual reality," *Journal of the Korea Computer Graphics Society,* vol. 24, no. 3, pp. 83-92, 2018.

[47] M. Al-Emran, "Evaluating the use of smartwatches for learning purposes through the integration of the technology acceptance model and task-technology fit," *International Journal of Human–Computer Interaction,* vol. 37, no. 19, pp. 1874-1882, 2021.

[48] T. K. Yu and T. Y. Yu, "Modelling the factors that affect individuals' utilisation of online learning systems: An empirical study combining the task technology fit model with the theory of planned behaviour," *British Journal of Educational Technology,* vol. 41, no. 6, pp. 1003-1017, 2010.

[49] D. L. Goodhue and R. L. Thompson, "Task-technology fit and individual performance," *MIS quarterly,* pp. 213-236, 1995.

[50] A. Parkes, "The effect of task–individual–technology fit on user attitude and performance: An experimental investigation," *Decision support systems,* vol. 54, no. 2, pp. 997-1009, 2013.

[51] Y. Liu, Y. Lee, and A. N. Chen, "Evaluating the effects of task–individual–technology fit in multi-DSS models context: A two-phase view," *Decision Support Systems,* vol. 51, no. 3, pp. 688-700, 2011.

[52] T. J. McGill and J. E. Klobas, "A task–technology fit view of learning management system impact," *Computers & Education,* vol. 52, no. 2, pp. 496-508, 2009.

[53] S. Cane and R. McCarthy, "Analyzing the factors that affect information systems use: a task-technology fit meta-analysis," *Journal of Computer Information Systems,* vol. 50, no. 1, pp. 108-123, 2009.

[54] J. Gikas and M. M. Grant, "Mobile computing devices in higher education: Student perspectives on learning with cellphones, smartphones & social media," *The Internet and Higher Education,* vol. 19, pp. 18-26, 2013.

[55] D. L. Goodhue, B. D. Klein, and S. T. March, "User evaluations of IS as surrogates for objective performance," *Information & management,* vol. 38, no. 2, pp. 87-101, 2000.

[56] K. Jung, V. T. Nguyen, D. Piscarac, and S.-C. Yoo, "Meet the virtual jeju dol harubang—The mixed VR/Ar application for cultural immersion in Korea's main heritage," *ISPRS International Journal of Geo-Information,* vol. 9, no. 6, p. 367, 2020.

[57] Z. Lai, Y. C. Hu, Y. Cui, L. Sun, and N. Dai, "Furion: Engineering high-quality immersive virtual reality on today's mobile devices," in *Proceedings of the 23rd Annual International Conference on Mobile Computing and Networking*, 2017, pp. 409-421.

[58] M. J. Liberatore and W. P. Wagner, "Virtual, mixed, and augmented reality: a systematic review for immersive systems research," *Virtual Reality,* vol. 25, no. 3, pp. 773-799, 2021.

[59] J. Cao, K.-Y. Lam, L.-H. Lee, X. Liu, P. Hui, and X. Su, "Mobile augmented reality: User interfaces, frameworks, and intelligence," *ACM Computing Surveys,* vol. 55, no. 9, pp. 1-36, 2023.

[60] X. Xu, D. Kilroy, E. Mangina, and A. G. Campbell, "Work-in-progress—Adapting a virtual reality anatomy teaching tool for mobility: Pilot study," in *2020 6th international conference of the immersive learning research network (iLRN)*, 2020: IEEE, pp. 328-331.

[61] A. Dengel, M. Z. Iqbal, S. Grafe, and E. Mangina, "A review on augmented reality authoring toolkits for education," *Frontiers in Virtual Reality,* vol. 3, p. 798032, 2022.

[62] C. Papakostas, C. Troussas, A. Krouska, and C. Sgouropoulou, "Measuring user experience, usability and interactivity of a personalized mobile augmented reality training system," *Sensors,* vol. 21, no. 11, p. 3888, 2021.

[63] H.-N. Do, W. Shih, and Q.-A. Ha, "Effects of mobile augmented reality apps on impulse buying behavior: An investigation in the tourism field," *Heliyon,* vol. 6, no. 8, 2020.

[64] J. Steuer, F. Biocca, and M. R. Levy, "Defining virtual reality: Dimensions determining telepresence," *Communication in the age of virtual reality,* vol. 33, pp. 37-39, 1995.
[65] S. J. McMillan and J.-S. Hwang, "Measures of perceived interactivity: An exploration of the role of direction of communication, user control, and time in shaping perceptions of interactivity," *Journal of advertising,* vol. 31, no. 3, pp. 29-42, 2002.
[66] B. Reeves and C. Nass, "The media equation: How people treat computers, television, and new media like real people," *Cambridge, UK,* vol. 10, no. 10, 1996.
[67] C. Latchem, *Interactive Multimedia: Practice and Promise*. ERIC, 1993.
[68] Z. Solomon, N. Ajayi, R. Raghavjee, and P. Ndayizigamiye, "Lecturers' perceptions of virtual reality as a teaching and learning platform," in *ICT Education: 47th Annual Conference of the Southern African Computer Lecturers' Association, SACLA 2018, Gordon's Bay, South Africa, June 18–20, 2018, Revised Selected Papers 47*, 2019: Springer, pp. 299-312.
[69] E. Pantano, A. Rese, and D. Baier, "Enhancing the online decision-making process by using augmented reality: A two country comparison of youth markets," *Journal of Retailing and Consumer Services,* vol. 38, pp. 81-95, 2017.
[70] H.-M. Huang and S.-S. Liaw, "An analysis of learners' intentions toward virtual reality learning based on constructivist and technology acceptance approaches," *International Review of Research in Open and Distributed Learning,* vol. 19, no. 1, 2018.
[71] N. C. Nilsson, R. Nordahl, and S. Serafin, "Immersion revisited: A review of existing definitions of immersion and their relation to different theories of presence," *Human technology,* vol. 12, no. 2, pp. 108-134, 2016.
[72] M. Slater and M. V. Sanchez-Vives, "Enhancing our lives with immersive virtual reality," *Frontiers in Robotics and AI,* vol. 3, p. 74, 2016.
[73] J. Mütterlein, "The three pillars of virtual reality? Investigating the roles of immersion, presence, and interactivity," 2018.
[74] B. G. Witmer and M. J. Singer, "Measuring presence in virtual environments: A presence questionnaire," *Presence,* vol. 7, no. 3, pp. 225-240, 1998.
[75] W. R. Sherman and A. B. Craig, *Understanding virtual reality: Interface, application, and design*. Morgan Kaufmann, 2018.
[76] P. Disztinger, S. Schlögl, and A. Groth, "Technology acceptance of virtual reality for travel planning," in *Information and Communication Technologies in Tourism 2017: Proceedings of the International Conference in Rome, Italy, January 24-26, 2017*, 2017: Springer, pp. 255-268.
[77] Y. Peng and D. Ke, "Consumer trust in 3D virtual worlds and its impact on real world purchase intention," *Nankai Business Review International,* vol. 6, no. 4, pp. 381-400, 2015.
[78] P. Milgram and F. Kishino, "A taxonomy of mixed reality visual displays," *IEICE TRANSACTIONS on Information and Systems,* vol. 77, no. 12, pp. 1321-1329, 1994.
[79] J. Kim and T. Leathem, "Virtual reality as a standard in the construction management curriculum," in *International Conference on Construction Futures*, 2018, pp. 1-13.
[80] J. J. Cummings and J. N. Bailenson, "How immersive is enough? A meta-analysis of the effect of immersive technology on user presence," *Media psychology,* vol. 19, no. 2, pp. 272-309, 2016.
[81] I. Heldal, "Supporting participation in planning new roads by using virtual reality systems," *Virtual Reality,* vol. 11, pp. 145-159, 2007.
[82] O. D. Kothgassner, A. Felnhofer, N. Hauk, E. Kastenhofer, J. Gomm, and I. Kryspin-Exner, "Technology Usage Inventory-Manual," *FFG: Wien, Austria,* 2012.
[83] H.-M. Huang, S.-S. Liaw, and C.-M. Lai, "Exploring learner acceptance of the use of virtual reality in medical education: a case study of desktop and projection-based display systems," *Interactive Learning Environments,* vol. 24, no. 1, pp. 3-19, 2016.
[84] Y. Salame *et al.*, "The Effects of Interactivity on Learners' Experience in a Visually Immersive Display Context," *Computers in the Schools,* vol. 39, no. 1, pp. 41-60, 2022.
[85] D.-H. Shin, "What makes consumers use VoIP over mobile phones? Free riding or consumerization of new service," *Telecommunications Policy,* vol. 36, no. 4, pp. 311-323, 2012.
[86] H. T. Verkasalo, "Empirical modelling of the mobile VoIP demand," in *Proceedings of the International MultiConference of Engineers and Computer Scientists*, 2008, vol. 1.
[87] H. Kynäslahti, "In search of elements of mobility in the context of education," *Mobile learning,* pp. 41-48, 2003.
[88] J. H. Huang, Y. R. Lin, and S. T. Chuang, "Elucidating user behavior of mobile learning: A perspective of the extended technology acceptance model," *The electronic library,* vol. 25, no. 5, pp. 585-598, 2007.
[89] K. Gillick and R. Vanderhoof, "Mobile e-commerce: marketplace enablers and inhibitors," in *Smart Card Forum Annual Meeting*, 2000, pp. 25-28.
[90] E. Park and K. J. Kim, "An integrated adoption model of mobile cloud services: exploration of key determinants and extension of technology acceptance model," *Telematics and Informatics,* vol. 31, no. 3, pp. 376-385, 2014.
[91] E. Park, S. Baek, J. Ohm, and H. J. Chang, "Determinants of player acceptance of mobile social network games: An application of extended technology acceptance model," *Telematics and Informatics,* vol. 31, no. 1, pp. 3-15, 2014.
[92] E. Park and A. P. del Pobil, "Extending the technology acceptance model in remote pointing technology: identifying the role of perceived mobility and control," *Sensor Review,* vol. 33, no. 1, pp. 40-47, 2013.
[93] F. D. Davis, "Perceived usefulness, perceived ease of use, and user acceptance of information technology," *MIS quarterly,* pp. 319-340, 1989.
[94] M. Fishbein and I. Ajzen, "Belief, attitude, intention, and behavior: An introduction to theory and research," 1977.
[95] I. Ajzen, "The theory of planned behavior," *Organizational behavior and human decision processes,* vol. 50, no. 2, pp. 179-211, 1991.
[96] C. M. Cheung, P.-Y. Chiu, and M. K. Lee, "Online social networks: Why do students use facebook?," *Computers in human behavior,* vol. 27, no. 4, pp. 1337-1343, 2011.
[97] E. W. Ngai, S. S. Tao, and K. K. Moon, "Social media research: Theories, constructs, and conceptual frameworks," *International journal of information management,* vol. 35, no. 1, pp. 33-44, 2015.
[98] W. Guest *et al.*, "A technology acceptance model for augmented reality and wearable technologies," *Journal of Universal Computer Science,* vol. 24, no. 2, pp. 192-219, 2018.
[99] T. Shemesh and S. Barnoy, "Assessment of the intention to use mobile health applications using a technology acceptance model in an Israeli adult population," *Telemedicine and e-Health,* vol. 26, no. 9, pp. 1141-1149, 2020.
[100] M. Rivera, A. Gregory, and L. Cobos, "Mobile application for the timeshare industry: The influence of technology experience, usefulness, and attitude on behavioral intentions," *Journal of Hospitality and Tourism Technology,* vol. 6, no. 3, pp. 242-257, 2015.
[101] S. T. Tokel and V. İsler, "Acceptance of virtual worlds as learning space," *Innovations in Education and Teaching International,* vol. 52, no. 3, pp. 254-264, 2015.
[102] F. Abd Majid and N. Mohd Shamsudin, "Identifying factors affecting acceptance of virtual reality in classrooms based on technology acceptance model (TAM)," *Asian Journal of University Education,* vol. 15, no. 2, pp. 1-10, 2019.
[103] V. Z. Vanduhe, M. Nat, and H. F. Hasan, "Continuance intentions to use gamification for training in higher education: Integrating the technology acceptance model (TAM), social motivation, and task technology fit (TTF)," *IEEE Access,* vol. 8, pp. 21473-21484, 2020.
[104] I. A. C. Jimenez, L. C. C. García, M. G. Violante, F. Marcolin, and E. Vezzetti, "Commonly used external tam variables in e-learning, agriculture and virtual reality applications," *Future Internet,* vol. 13, no. 1, pp. 1-21, 2020.
[105] S. Alharbi and S. Drew, "Using the technology acceptance model in understanding academics' behavioural intention to use learning management systems," 2014.

[106] V. Venkatesh, "Determinants of perceived ease of use: Integrating control, intrinsic motivation, and emotion into the technology acceptance model," *Information systems research,* vol. 11, no. 4, pp. 342-365, 2000.
[107] J. Lu, "Are personal innovativeness and social influence critical to continue with mobile commerce?," *Internet research,* vol. 24, no. 2, pp. 134-159, 2014.
[108] W. R. King and J. He, "A meta-analysis of the technology acceptance model," *Information & management,* vol. 43, no. 6, pp. 740-755, 2006.
[109] M. Fetscherin and C. Lattemann, "User acceptance of virtual worlds," *Journal of electronic commerce research,* vol. 9, no. 3, p. 231, 2008.
[110] M. Bertrand and S. Bouchard, "Applying the technology acceptance model to VR with people who are favorable to its use," *Journal of Cyber Therapy & Rehabilitation,* vol. 1, no. 2, pp. 200-210, 2008.
[111] M. Chow, D. K. Herold, T.-M. Choo, and K. Chan, "Extending the technology acceptance model to explore the intention to use Second Life for enhancing healthcare education," *Computers & education,* vol. 59, no. 4, pp. 1136-1144, 2012.
[112] U. Alturki and A. Aldraiweesh, "Adoption of Google Meet by Postgraduate Students: The Role of Task Technology Fit and the TAM Model," *Sustainability,* vol. 14, no. 23, p. 15765, 2022.
[113] T. Chen, J. Chen, C. K. Or, and F. P. Lo, "Path analysis of the roles of age, self-efficacy, and TAM constructs in the acceptance of performing upper limb exercises through immersive virtual reality games," *International Journal of Industrial Ergonomics,* vol. 91, p. 103360, 2022.
[114] U. Riedlinger, L. Oppermann, and W. Prinz, "Tango vs. HoloLens: A comparison of collaborative indoor AR visualisations using hand-held and hands-free devices," *Multimodal Technol. Interact.,* vol. 3, no. 2, p. 23, 2019 2019, doi: 10.3390/mti3020023.
[115] J. Newnham, *Microsoft HoloLens By Example*. Birmingham, England: Packt Publishing, 2017.
[116] J. F. Hair, M. Sarstedt, C. M. Ringle, and J. A. Mena, "An assessment of the use of partial least squares structural equation modeling in marketing research," *Journal of the academy of marketing science,* vol. 40, pp. 414-433, 2012.
[117] R. V. Krejcie and D. W. Morgan, "Determining sample size for research activities," *Educational and psychological measurement,* vol. 30, no. 3, pp. 607-610, 1970.
[118] J. Nunnally, "Psychometric theory," *(No Title),* 1994.
[119] M. Ab Hamid, W. Sami, and M. M. Sidek, "Discriminant validity assessment: Use of Fornell & Larcker criterion versus HTMT criterion," in *Journal of Physics: Conference Series*, 2017, vol. 890, no. 1: IOP Publishing, p. 012163.
[120] D. Mitrany, "Methodology of the Social Sciences," *Nature,* vol. 156, no. 3958, pp. 278-279, 1945/09/01 1945, doi: 10.1038/156278a0.
[121] J. F. Hair Jr, G. T. M. Hult, C. Ringle, and M. Sarstedt, "A primer on partial least squares structural equation modeling (PLS-SEM) Sage Publications," *Thousand Oaks, CA, USA,* 2016.
[122] J. F. Hair Jr, M. Sarstedt, C. M. Ringle, and S. P. Gudergan, *Advanced issues in partial least squares structural equation modeling*. saGe publications, 2017.
[123] J. F. Hair Jr, M. Sarstedt, L. Hopkins, and V. G. Kuppelwieser, "Partial least squares structural equation modeling (PLS-SEM): An emerging tool in business research," *European business review,* vol. 26, no. 2, pp. 106-121, 2014.
[124] C. Fornell and D. F. Larcker, "Structural equation models with unobservable variables and measurement error: Algebra and statistics," ed: Sage Publications Sage CA: Los Angeles, CA, 1981.
[125] J. Hair Jr, J. F. Hair Jr, G. T. M. Hult, C. M. Ringle, and M. Sarstedt, *A primer on partial least squares structural equation modeling (PLS-SEM)*. Sage publications, 2021.
[126] N.-H. Chen, "Extending a TAM–TTF model with perceptions toward telematics adoption," *Asia Pacific Journal of Marketing and Logistics,* vol. 31, no. 1, pp. 37-54, 2019.
[127] Y.-Y. Shih and C.-Y. Chen, "The study of behavioral intention for mobile commerce: via integrated model of TAM and TTF," *Quality & Quantity,* vol. 47, pp. 1009-1020, 2013.
[128] S. Rahi, M. M. Khan, and M. Alghizzawi, "Extension of technology continuance theory (TCT) with task technology fit (TTF) in the context of Internet banking user continuance intention," *International Journal of Quality & Reliability Management,* vol. 38, no. 4, pp. 986-1004, 2021.
[129] A. Yaakop, Y. Shi, B. Foster, and J. Saputr, "Investigating e-wallet adoption of COVID19 intra-period among Malaysian youths': Integrated task-technology fit and technology acceptance model framework," *International Journal of Data and Network Science,* vol. 5, no. 3, pp. 295-302, 2021.
[130] A. F. Alkhwaldi and A. A. Abdulmuhsin, "Understanding User Acceptance of IoT Based Healthcare in Jordan: Integration of the TTF and TAM," in *Digital Economy, Business Analytics, and Big Data Analytics Applications*: Springer, 2022, pp. 191-213.
[131] S.-S. Liaw and H.-M. Huang, "Perceived satisfaction, perceived usefulness and interactive learning environments as predictors to self-regulation in e-learning environments," *Computers & Education,* vol. 60, no. 1, pp. 14-24, 2013.
[132] B. Rahmi, B. Birgoren, and A. Aktepe, "A meta analysis of factors affecting perceived usefulness and perceived ease of use in the adoption of e-learning systems," *Turkish Online Journal of Distance Education,* vol. 19, no. 4, pp. 4-42, 2018.
[133] A. J. Barrett, A. Pack, and E. D. Quaid, "Understanding learners' acceptance of high-immersion virtual reality systems: Insights from confirmatory and exploratory PLS-SEM analyses," *Computers & Education,* vol. 169, p. 104214, 2021.
[134] S. M. Sepasgozar, "Immersive on-the-job training module development and modeling users' behavior using parametric multi-group analysis: A modified educational technology acceptance model," *Technology in Society,* vol. 68, p. 101921, 2022.
[135] R. Tjandra, D. P. Alamsyah, and L. Susanti, "Perceived Mobility of Mobile Payments: Mediation Model of User Usefulness," in *2021 International Seminar on Machine Learning, Optimization, and Data Science (ISMODE)*, 2022: IEEE, pp. 228-232.
[136] N. A. Othman, D. P. Alamsyah, C. Ratnapuri, and D. Kurnianingrum, "The Perceived Ease of Use In Mobile Payment Support by Responsiveness Smartness and Mobility," *J Theor Appl Inf Technol,* vol. 100, no. 11, pp. 3696-3706, 2022.
[137] A. Li, Y. Sun, X. Yang, and J. Guo, "Exploring the relationship between perceived ease of use and continuance usage of a mobile terminal: Mobility as a moderator," *Sustainability,* vol. 11, no. 4, p. 1128, 2019.
[138] Z. Kalinic and V. Marinkovic, "Determinants of users' intention to adopt m-commerce: an empirical analysis," *Information Systems and e-Business Management,* vol. 14, pp. 367-387, 2016.
[139] D. C. Yen, C.-S. Wu, F.-F. Cheng, and Y.-W. Huang, "Determinants of users' intention to adopt wireless technology: An empirical study by integrating TTF with TAM," *Computers in Human Behavior,* vol. 26, no. 5, pp. 906-915, 2010.
[140] T. Piumsomboon, A. Dey, B. Ens, G. Lee, and M. Billinghurst, "The effects of sharing awareness cues in collaborative mixed reality," *Frontiers in Robotics and AI,* vol. 6, p. 5, 2019.
[141] N. Ishfaq and H. Mengxing, "Consumer usage behavior of internet-based services (IBS) in Pakistan during COVID-19 crisis from the perspective of technology acceptance model," *Environmental Science and Pollution Research,* pp. 1-16, 2021.
[142] Y. Kurniawan, S. Candra, and L. Y. Tungka, "E-learning: MOOC user intention analysis using TAM and TTF with social motivation factor and MOOC features," in *Digital Literacy and Socio-Cultural Acceptance of ICT in Developing Countries*. Cham: Springer International Publishing, 2021, pp. 101-117.
[143] M. Park and J. Yoo, "Effects of perceived interactivity of augmented reality on consumer responses: A mental imagery perspective," *Journal of Retailing and Consumer Services,* vol. 52, p. 101912, 2020.
[144] A. Shankar and B. Datta, "Factors affecting mobile payment adoption intention: An Indian perspective," *Global Business Review,* vol. 19, no. 3_suppl, pp. S72-S89, 2018.
[145] T. Xie, L. Zheng, G. Liu, and L. Liu, "Exploring structural relations among computer self-efficacy, perceived immersion, and intention to use virtual reality training systems," *Virtual Reality,* vol. 26, no. 4, pp. 1725-1744, 2022.

[146] M. Ghobadi, S. Shirowzhan, M. M. Ghiai, F. Mohammad Ebrahimzadeh, and F. Tahmasebinia, "Augmented Reality Applications in Education and Examining Key Factors Affecting the Users' Behaviors," *Education Sciences,* vol. 13, no. 1, p. 10, 2022.

[147] G. B. Petersen, G. Petkakis, and G. Makransky, "A study of how immersion and interactivity drive VR learning," *Computers & Education,* vol. 179, p. 104429, 2022.

[148] E. T. Lwoga and N. B. Lwoga, "User acceptance of mobile payment: The effects of user-centric security, system characteristics and gender," *The Electronic Journal of Information Systems in Developing Countries,* vol. 81, no. 1, pp. 1-24, 2017.

[149] F. Abdullah, R. Ward, and E. Ahmed, "Investigating the influence of the most commonly used external variables of TAM on students' Perceived Ease of Use (PEOU) and Perceived Usefulness (PU) of e-portfolios," *Computers in human behavior,* vol. 63, pp. 75-90, 2016.

[150] P. Verma and N. Sinha, "Role of attitude as mediator of the perceived ease of use and behavioural intention relationship," *International Journal of Management Concepts and Philosophy,* vol. 10, no. 3, pp. 227-245, 2017.

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