Agency and Knowledge in Practice: Why Trainers´Attitude Matters in Virtual Simulation-based Training

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Abstract. Immersive learning as virtual simulation-based training is increasingly recognised as an effective approach in safety-critical contexts. However, despite the pedagogical potential of this training, the implementation of VR technologies in teaching practice remains rather limited. This study examines the relationship between trainers' technological pedagogical content knowledge, teacher agency, and attitude towards virtual simulation use to predict the actual virtual simulations use in teaching. The study is based on two independent questionnaire surveys conducted in 2022 (n = 47) and 2026 (n = 59) among staff in Estonian rescue college. Survey responses were analysed using descriptive statistics to assess the extent of virtual simulation use and binary logistic regression to identify factors associated with its adoption in training practice. The results indicate that neither knowledge nor agency significantly predict virtual simulations use in training. Simultaneously, attitude towards virtual simulations use emerged as a significant predictor. These findings suggest that the implementation of immersive learning in safety-critical training is not primarily driven by trainers´ knowledge or contextual factors, but by trainers' perceptions of the relevance and value of the virtual simulation-based training.

Keywords: virtual simulations (VS), virtual simulation-based training (VSBT), technological pedagogical content knowledge (TPACK), attitude towards virtual simulations use (AVSU), teacher agency

1 Introduction

In this study, immersive learning is conceptualised through the virtual simulations (VS) use to do virtual simulations-based training (VSBT). *Virtual simulations* (VS) are defined as scenarios or problem-based tasks presented using virtual reality technologies (both software and hardware) that imitate processes or activities related to working life, with the aim of developing trainees' competencies [23]. *Virtual reality* (VR) is conceptualised as one of the immersive technologies, a subset of extended reality (XR), and a digital learning tool that enables VSBT environments [21]. VR tools are increasingly integrated into safety-critical

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training contexts such as civil protection and crisis management [14], where it offers the potential to enhance situational awareness [21], support decision-making processes [19], and provide safe environments for practicing complex and high-risk scenarios [20]. Our perspective is, that immersive learning is an interactive, technology-enhanced approach that enables experiential engagement, situational awareness, and time critical decision-making training within digitally simulated professional environments.

VSBT is considered a promising approach for preparing professionals such as firefighters and incident commanders [1] [7] [19]. However, the effectiveness of VSBT does not stem solely from the technology itself, but rather from how trainers coordinate pedagogy, teamwork, and organisational support across the entire training process [1]. Therefore, the actual adoption of VR tools in firefighters training practices remains uneven [25]. While access to immersive technologies has improved and their potential benefits are widely recognised, their use in everyday training settings is still limited. This raises an important question: why do trainers not use VSBT in their teaching practice, even in situations where the VR tools are available?

Previous research has primarily focused on *technological pedagogical content knowledge* (TPACK) as a key factor influencing technology integration in education [9, 13]. TPACK describes how trainers combine technological, pedagogical, and content knowledge in order to design VSBT learning experiences [23]. In the context of VSBT, high levels of TPACK are assumed to support the meaningful use of immersive technologies [23]. Empirical studies also suggest that increased technological knowledge is associated with greater confidence and willingness to use digital tools [27]. However, there is growing evidence that high self-reported TPACK does not necessarily translate into enacted use of technology in practice [15, 23].

To complement knowledge roles, research has increasingly turned to teacher agency as a complementary perspective. *Teacher agency* refers to trainers' capacity to make professional decisions and actively shape their instructional practices within specific organisational and social contexts [2, 3]. Agency highlights that technology integration is not only a matter of trainers' knowledge but also of decision-making, motivation, and contextual constraints. In safety-critical training environments, where authenticity and practical relevance are highly valued, trainers may exercise agency by selecting or rejecting technologies based on their perceived suitability for achieving learning objectives [12].

In addition to TPACK and agency, attitudes towards technology have been identified as an important factor influencing use of VSBT in teaching [16]. *Attitudes* reflect how trainers perceive the usefulness, relevance, and pedagogical value of technological tools. In immersive learning contexts, attitudes may be particularly important, as the perceived relevance and applicability of VSBT can directly influence whether trainers consider VS appropriate for training purposes [23]. Previous research in vocational education context has shown that attitude towards virtual simulations use (AVSU) is closely linked to VSBT implementation [23].

However, despite the recognition of these three perspectives —knowledge (TPACK), agency, and attitude—there is limited empirical evidence comparing their relative importance in explaining actual technology use in real-world safety-critical training contexts such as a Rescue College. In particular, it remains unclear whether TPACK and agency are sufficient to explain VSBT, or whether attitudinal factors play a more central role.

This study addresses this gap by examining the relationship between trainers' TPACK, teacher agency, AVSU, and use of VS in a firefighters training context. The study draws on two independent datasets collected in 2022 [23] and 2026 [29] within the same organisational setting. By combining these perspectives, the study aims to better understand the factors that explain the gap between trainers' TPACK, agency, attitude and actual VS use in teaching.

The contribution of this paper is twofold. First, it provides empirical evidence on the relative importance of TPACK, agency, and AVSU explanations of use of VSBT in authentic firefighters training context. Second, it advances the understanding of technology integration in practice by demonstrating that adoption cannot be explained solely by knowledge, agency or contextual factors, but must also account for trainers' perceptions of the value, usefulness and relevance of immersive technologies.

This study contributes to several key themes of the SAFAR conference. First, it advances the understanding of immersive learning by examining how many trainers use VS in safety-critical training context. Second, it addresses technology-enhanced learning by empirically identifying factors connected to trainers that influence the use of VS. Third, it contributes to crisis management and decision-support training by focusing on possibility to provide immercive learning experiences using VSBT.

2 Related Work

2.1 The Technological Pedagogical Content Knowledge Framework

The Technological Pedagogical Content Knowledge (TPACK) framework [9] [13] provides a widely used model for understanding how trainers integrate technology into teaching practice. TPACK emphasises the interaction between four domains of knowledge: technological knowledge (TK), pedagogical knowledge (PK) and content knowledge (CK) as well Contextual Knowledge (XK) [13]. The framework further highlights their intersections, including technological pedagogical knowledge (TPK), technological content knowledge (TCK), pedagogical content knowledge (PCK) and the integrative construct of technological pedagogical content knowledge (TPCK, measured with five items [28]). TPACK framework measured with 42 items represents the measurement tool to estimate trainers´ ability to effectively combine all domains in instructional design and implementation in concrete training context [13] [28].

In the context of VSBT, such technology as extended reality (XR) and its subtechnology virtual reality (VR) [21], TPACK offers a useful lens for analysing

trainers' readiness to use advanced technologies. VSBT requires not only technical proficiency but also the ability to align immersive tools with pedagogical strategies and domain-specific learning objectives [23]. For example, effective use of VSBT depends on the instructor's capacity to design scenarios that support situational awareness, decision-making, and experiential learning [22].

Previous research has demonstrated that higher levels of TPACK are associated with increased confidence in using digital tools [27] and greater willingness to experiment with innovative teaching methods [4]. In VSBT, technological pedagogical knowledge (TPK) is particularly relevant, as it involves selecting and adapting technologies to support specific instructional approaches, such as problem-based learning or scenario-based training [19]. Similarly, TPACK is critical for ensuring that immersive environments meaningfully represent domain-specific phenomena [5].

However, both prior research and empirical findings in the field suggest that high self-reported TPACK knowledge does not necessarily lead to sustained use of immersive technologies in practice, as their implementation is shaped by contextual, organisational, and pedagogical factors [1] [23].

Although the TPACK framework provides an important lens for understanding trainers technological and pedagogical knowledge, it offers only a partial explanation of VS use in practice. Since it captures individual knowledge structures, it does not fully account for the contextual, organisational, and sociocultural factors that influence whether TPACK is translated into enactment. Consequently, additional perspectives, such as teacher agency, are necessary to understand how trainers make decisions about VSBT in the real-world training context.

2.2 Teacher Agency

Teacher agency refers to trainers' capacity to make professional decisions and purposefully influence their teaching within specific training contexts [3]. Agency is viewed as a dynamic process emerging through the interaction between trainers and their professional environment [2]. Rather than relying solely on individual knowledge, pedagogical decisions are shaped by organisational conditions, available resources, collegial support, and the broader social context [2] [12].

The ecological model of teacher agency provides a useful framework for understanding these interactions [24]. According to this model, agency emerges through the interplay of three dimensions: the iterational dimension, which draws on past experiences and professional knowledge; the projective dimension, which relates to future goals and aspirations; and the practical-evaluative dimension, which concerns decision-making in the present situation while considering available resources, constraints, and contextual conditions [12] [24]. Agency therefore reflects not only what trainers are capable of doing, but also what they perceive as meaningful, feasible, and appropriate within a particular training setting [2].

The ecological model perspective is particularly relevant in safety-critical and vocational education contexts, where teachers often possess strong professional

expertise derived from practical field experience. In such environments, pedagogical decisions are influenced not only by pedagogical considerations but also by professional norms, operational practices, and perceptions of authenticity in training [6]. Trainers may therefore evaluate new technologies not only on the basis of technical knowledge but also according to their perceived relevance for achieving learning outcomes and preparing learners for real-world situations.

Trainers may possess the knowledge required to use immersive technologies but still choose not to adopt them due to organisational constraints, limited pedagogical fit, lack of support, or competing instructional priorities. Teacher agency therefore offers an important complementary perspective for understanding the gap between knowledge and actual use of VS. By focusing on how trainers navigate organisational conditions, social relationships, and pedagogical decision-making processes, agency helps to explain the adoption of VSBT.

2.3 Attitude Towards Virtual Simulations Use

In addition to TPACK and agency, trainers' attitude towards technology play an important role in the adoption of innovative teaching practices. AVSU reflect how trainers perceive the usefulness, relevance, and pedagogical value of VR-based training tools, and are closely related to their willingness to use such technologies in practice [23]. As shown by Polikarpus et al. (2023) [23], positive attitudes towards virtual simulations are associated with more enacted TPACK, including creating and implementing VS scenarios.

Furthermore, AVSU are shaped through experience. Trainers who actively use, design, or teach others to use VS tend to have more positive attitude compared to those with limited exposure [23, 19]. This suggests that AVSU is not only a personal perception but also connected to participation in VSBT implementation processes in specific training organisations.

Therefore, AVSU provides an important complementary perspective to TPACK and teacher agency, as it captures the perceptual dimension influencing whether VR tools are actually adopted in training practice.

3 Methodology

3.1 Research Design and Research Questions

The aim of this study is to examine how trainers' TPACK, agency, and AVSU predict the actual use of VS in training practice within a Rescue College context in Estonia. The study was conducted at the Estonian Academy of Security Sciences (EASS), the largest state-owned higher education institution under the Estonian Ministry of the Interior. As the primary provider of education and professional training for Estonia's internal security sector, EASS represents a unique educational environment where trainers combine academic instruction with profession-specific practical training across several security-related disciplines [23]. This study employs a comparative research design and logistic regression based on two independent datasets collected in 2022 [23] and 2026

[29] within the same Rescue College. The datasets are analysed separately due to anonymised data collection procedures that prevented matching individual trainers across time. The design allows to examine predictors (TPACK, AVSU, agency, work and teaching experience) of the VS use.

The study addresses the following two research questions:

- RQ1: To what extent are VS used in teaching practice in 2022 and 2026 in the Rescue College?
- RQ2: Which factors (TPACK, AVSU, teacher agency, and experience) predict VS use in training practice?

3.2 Participants

The study includes two independent samples of trainers from EASS Rescue College. In the 2022 dataset, 47 responses were collected, and in the 2026 dataset, 59 responses were collected. Participants represented the teaching staff responsible for both vocational and higher education programmes in the field of rescue services. The sample included both full-time and contracted trainers who delivered theoretical and practical instruction in vocational curricula (rescuer, dispatcher, and rescue team leader programmes) as well as in higher education curricula related to rescue services. Thus, the respondents represented a range of educational roles within the organisation, covering both academic and practice-oriented training activities.

The average age of participants was 43.4 years (SD = 9.4) in 2022 and 41.1 years (SD = 8.3) in 2026, indicating comparable age distributions across the samples. Gender distribution did not differ significantly between the datasets ($\chi^2(1) = .064$, $p = .801$), and no significant differences in age were found ($t = 1.342$, $df = 101$, $p = .183$). In the 2026 dataset, trainers reported an average work experience of 16.50 years (SD = 9.33) and an average teaching experience of 8.63 years (SD = 6.60).

3.3 Measures

For logistic regression the dependent variable, VS use, was measured as a binary variable, where 0 indicates non-use and 1 indicates the use of VS in training. In 2022 dataset multiple choice questions was coded to VS users and non-users [23] and in 2026 dataset the question "Have you used VS in your teaching?" had Yes and No answers.

TPACK (2022 dataset): Trainers' TPACK was measured using a composite TPACK score computed across all relevant survey items [28] [23].

AVSU (2022 dataset): attitude towards virtual simulation use were measured using a four-item scale adapted from previous studies [23].

The reliability of the instruments was evaluated using Cronbach's alpha. The TPACK scale demonstrated good internal consistency ($\alpha = 0.89$), while the AVSU instrument demonstrated excellent internal consistency ($\alpha = 0.91$).

Agency (2026 dataset): Trainers' agency was measured using a validated multi-item survey instrument [11]. An agency composite score was calculated by averaging responses across all 24 items to provide a parsimonious representation of the construct [29]. The Agency scale demonstrated good internal consistency, with a Cronbach's alpha coefficient of $\alpha = 0.88$, exceeding the commonly accepted threshold of 0.70 for reliable measurement and indicating that the items reliably measured the underlying construct.

Work experience and teaching experience (in years) were included as control variables in the 2026 dataset. TPACK, AVSU were measured on a five-point Likert scale (1 = strongly disagree to 5 = strongly agree) while agency was measured a seven-point Likert scale (1 = strongly disagree to 7 = strongly agree).

3.4 Data Analysis

Statistical analyses were conducted using JASP software (version JASP 0.18.3) [8]. Descriptive statistics were used to summarise sample characteristics and independent variables. Differences between datasets were examined using independent samples t-tests (age) and chi-square tests (gender).

To examine predictors of VS use, logistic regression analyses [26] were conducted. This method was selected because the dependent variable (VS use) is binary (VS use (1) and non-use of VS (0)). For each dataset separate models were used to assess what predicts the likelihood of VSBT. To reduce model complexity and avoid multicollinearity, composite variables were used for TPACK and agency. Model fit was evaluated using chi-square statistics and Nagelkerke R^2 which indicates the explanatory power of the model. The magnitude of R^2 was interpreted as an approximate indication of effect size. Both single-predictor and multiple logistic regression models were estimated. However, only the multiple regression models are reported, as they reflect the unique contribution of each predictor.

4 Results

Because different constructs were measured in the 2022 and 2026 datasets, the analyses were conducted separately for each dataset. The 2022 dataset included TPACK and AVSU, whereas the 2026 dataset included agency, work experience, and teaching experience (see also Fig. 1 below).

4.1 Virtual simulations use in the Rescue College Training Practice 2022 and 2026

First we asked to what extent are VS used in teaching practice in 2022 and 2026 (RQ1). Descriptive analysis showed that the use of VR-based simulation tools varied across the datasets (see Table 1). In the 2022 sample, approximately half of the trainers reported using VS in their teaching. In more detail, out of 47 participants 23 (49%) had not used virtual simulations as trainers in their

teaching and 24 (51%) had used it or created simulations themselves or trained even others how to use VS in teaching. One participant in 2026 sample did not answer this voluntary question. Therefore, out of 58 participants 38 (65.5%) reported that they have not used VS in training and 20 (34,5%) reported they had used VS. Therefore, the proportion of VS users was lower in the 2026 sample than in the 2022 sample. However, the difference between the two datasets was not statistically significant ($\chi^2(1) = 2.93$, $p = .087$), indicating that the overall level of VS use in Rescue College remained relatively stable.

Table 1. Trainers using or not virtual simulations (VS) in their training in Rescue College

	Groups		
VS use	2022	2026	Total
No	23; (49%)	38; (65, 5%)	61
Yes	24; (51%)	20; (34, 5%)	44
Total	47; (100%)	58; (100%)	105

4.2 Predictors of virtual simulations use

The binary logistic regression analyses predicting VS use in 2022 and 2026 datasets to answer our RQ2 about which factors among TPACK, AVSU, teacher agency and experiences significantly predict VS use in training practice was conducted. In Appendix Table 3 all five independent variables mean scores, standard deviations and minimum and maximum results could be found.

2022 model where TPACK and trainers' AVSU were the statistically significant predictor of VS use ($\chi^2(1) = 10.99, p < .004$) was AVSU (see Table 2). The 2022 model explanatory power Nagelkerke $R^2 = .28$, indicating that the model has moderate explanatory power regarding VS use. In addition, the odds ratio for AVSU ($p = .014$, OR = 3.70, 95% CI [1.31, 10.50]) indicates that a one-unit increase in AVSU was associated with approximately 3.7 times higher odds of using VSBT, compared to TPACK odds ratio (OR) that was 1.13.

Teacher agency, work experience, and teaching experience in 2026 model did not significantly predict VS use ($p \succ .05$). 2026 model demonstrated low explanatory power (Nagelkerke $R^2 = .06$), and the corresponding confidence intervals for the odds ratios included 0.62 to 1.03, indicating no statistically reliable effects (see Table 2).

In addition, other logistic regression models were estimated. We tested other predictors from TPACK framework like TK, TPK, TCK, TPCK, the three dimensions of teacher agency ecological model (the iterational, projective, and practical-evaluative dimensions), work experience and teaching experience but none of them gave statistically signifficant results. These findings suggest that TPACK and agency-related factors were not statistically significant predictors of VS use in this context.

Table 2. Logistic regression models predicting VS use in Rescue College 2022 and 2026 datasets

	2022 model	**2026 model**
Predictors		
TPACK (composite)	.12 (1.13) [.41, 3.12]	–
AVSU (composite)	1.31 (3.70)* [1.31, 10.49]	–
Agency (composite)	–	-.48 (.62) [.25, 1.54]
Work experience	–	.03 (1.03) [.95, 1.12]
Teaching experience	–	-.00 (1.00) [.90, 1.11]
Model fit		
χ^2 (df)	10.99 (2)**	2.50 (3)
p-value	.004	.475
Nagelkerke R^2	.28	.06

Note. Values are B (odds ratio) with 95% confidence intervals in brackets. * $p < .05$, ** $p < .01$.

5 Discussion

The findings related to the extent to which VS were used in teaching practice in 2022 and 2026 (RQ1) indicate that the use of VS remained relatively stable in the Rescue College context. Approximately half of the trainers reported using VSBT in 2022, whereas the proportion was somewhat lower in 2026. A possible explanation for this statistically non-significant difference may be variation in sample composition. These findings suggest that, despite the availability of immersive technologies, their integration into everyday training practice remains limited to trainers willing to adopt new technologies in their teaching. Compared with other colleges in the same training organisation in 2022, Rescue College had the highest proportion of VS users among survey participants [23]. That study also showed that trainers with higher integrated TPACK and AVSU were more likely to use VSBT. However, due to the cross-sectional research design it remained unclear whether more positive attitudes led to VS use or whether VS use resulted in more positive attitudes [23]. Therefore, a bidirectional arrow is used in the 2022 model shown in Fig. 1. Further research is needed to better understand the development of immersive technology use over time.

The results indicate that TPACK does not significantly predict VS use (RQ2), despite its strong theoretical grounding in technology integration research (see Table 2 and Fig. 1). This finding aligns with previous studies suggesting that high levels of self-reported TPACK do not necessarily translate into the actual implementation of immersive technologies in practice [10] [15]. While TPACK captures trainers' ability to integrate technological, pedagogical, and content knowledge in specific training context [13], it does not fully account for whether such knowledge is enacted in real training situations [23]. In safety-critical contexts, where instructional decisions are closely tied to practical relevance and authenticity, possessing knowledge alone appears insufficient to drive the VSBT.

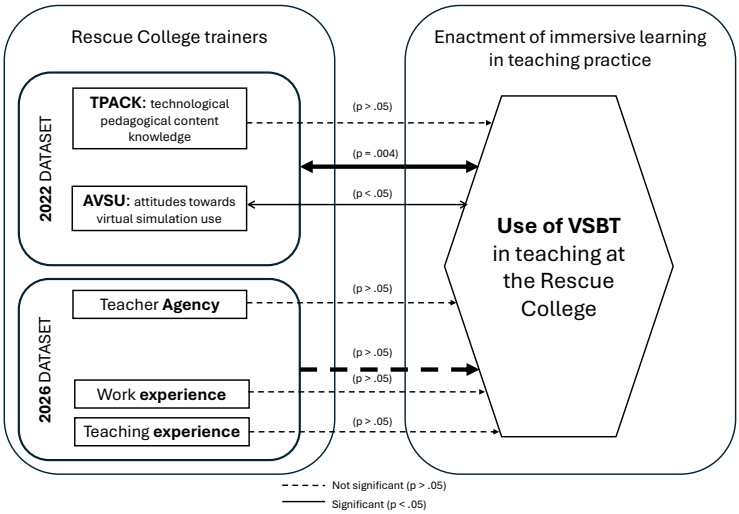


Fig. 1. Conceptual summary of logistic regression results. Solid arrows indicate a statistically significant relationship ($p \prec .05$), whereas dashed arrows indicate non-significant relationships ($p \geq .05$). Only AVSU significantly predicted VS use in training practice.

Unexpectedly, teacher agency was not found to significantly predict VS use (Fig. 1). Although agency is widely recognised as a key factor in explaining professional decision-making and the implementation of educational innovations [3] [12], the findings suggest that agency alone does not explain whether trainers use VSBT in practice. This is consistent with the ecological perspective of agency, which emphasises that professional action emerges from the interaction between individual capacities, organisational conditions, and contextual constraints [2]. Even when trainers have the ability to make autonomous pedagogical decisions, these decisions may not favour VSBT if the technology is not perceived as meaningful or appropriate for achieving training objectives.

As expected, AVSU emerged as the only significant predictor of VS use, even when controlling for TPACK and other variables (see Table 2 and Fig. 1). This finding highlights the central role of perceptual and evaluative factors in shaping technology adoption. The strength of the effect (OR = 3.70) indicates that trainers with more positive attitude are substantially more likely to use VSBT in their teaching practice. This result supports earlier research demonstrating that attitude towards technology is closely linked to its implementation in firefighters training contexts [19]. In immersive learning environments, such an attitude is likely influenced by perceived usefulness, relevance, and pedagogical value, which directly affect whether VSBT is considered appropriate for training purposes. This is in line with the fact that trainers emphasize pedagogical redesign, clear objectives and adaption to trainee needs [1]. In safety-critical training contexts, these perceptions are closely linked to the authenticity and practical applicability

of VS training scenarios [20]. Trainers may therefore choose not to adopt VR-based solutions if they perceive them as less effective than established hands-on approaches [7], regardless of their knowledge or decision-making capacity (measured as agency).

From a theoretical perspective, the findings contribute to ongoing discussions about the limitations of knowledge-based models of technology integration. We reinforce the view that knowledge alone does not lead to implementation, and that attitudinal factors must be considered alongside knowledge and contextual conditions. From a practical perspective, the results imply that efforts to promote VSBT should not focus solely on developing knowledge or increasing organisational support. Rather, greater emphasis should be placed on shaping positive attitude by demonstrating the pedagogical effectiveness and training value of VSBT [19]. Without such alignment between technology and perceived instructional value, the adoption of immersive technologies is likely to remain limited.

The findings also have practical implications for increasing the adoption of immersive learning technologies. As positive attitudes towards VSBT were associated with actual use, trainers may be motivated through opportunities to experience successful VSBT, observe its educational benefits, and exchange good practices with colleagues. In addition, VR tools should be integrated as pedagogically meaningful components of existing training activities rather than as stand-alone technological innovations. Such an approach may strengthen perceived usefulness and support wider adoption of immersive learning.

Taken together, the results of RQ1 and RQ2 suggest that the moderate level of VSBT cannot be explained by differences in knowledge, agency or experiences, but is more closely associated with trainers' attitude towards the use of VS. In this sense, VSBT appears to be guided less by what trainers can do, and more by what they consider worth doing in their specific training context.

5.1 Limitations and Future Studies

This study has several limitations that should be considered when interpreting the findings. First, although the study combines two datasets collected within the same organisational context in a four-year period, the surveys were conducted at different time points (2022 and 2026) and were fully anonymous. Consequently, it was not possible to match individual trainers across the datasets or examine changes in the same trainer using VSBT over time. The findings should therefore be interpreted as comparisons between two independent samples rather than longitudinal changes at the individual level. Therefore, future studies should combine TPACK, AVSU and agency into same survey and follow the individual trainers experience and attitude changes over time.

Second, the study was conducted within a single Rescue College. Although this provided a consistent organisational context to compare TPACK [13], teacher agency, AVSU, and VS use, the findings may not be directly generalisable to other vocational education institutions or safety-critical training organisations with different organisational cultures, technological resources, or pedagogical

practices. However, further studies should also take into account the context as this study does.

Third, all variables were measured using self-report questionnaires. Although validated instruments were employed [11] [23] [28], self-report measures are susceptible to common method bias, response bias, and social desirability, which can inflate or attenuate relationships between variables [18]. As highlighted in more recent methodological guidance, common method bias is a complex and widespread issue that cannot be completely eliminated through statistical procedures alone and should primarily be addressed through careful research design [17]. Therefore, future research should use beside survey other methods to evaluate the VS use by trainers to offer immersive learning experiences.

Finally, VS use was measured as a binary outcome (use versus non-use), which does not capture differences in the frequency, intensity, or pedagogical quality of VSBT. Future studies could employ more fine-grained measures of technology use and longitudinal research designs to examine how trainers' knowledge, agency, attitude, and instructional practices develop over time.

6 Conclusion

This study examined the relationships among trainers' technological pedagogical content knowledge (TPACK), attitude towards virtual simulation use (AVSU), teacher agency, and experience in explaining the actual use of VS. The results showed that neither TPACK nor teacher agency significantly predicted VS use, whereas AVSU emerged as the only statistically significant predictor.

These findings highlight a gap between technological-pedagogical knowledge, teacher agency, and actual instructional practice. The use of VSBT in safety-critical training environments appears to be more strongly associated with how trainers perceive the pedagogical value, usefulness, and relevance of immersive technologies than with the variables examined in this study.

From a practical perspective, these findings suggest that promoting VSBT should focus not only on developing trainers' knowledge and agency but also on strengthening positive attitude by demonstrating the usefulness, relevance, and pedagogical value of VS. Future research should further explore how trainers' attitudes develop and how organisational support, opportunities for hands-on VR experiences, and sharing of successful implementation practices can encourage wider adoption of immersive learning technologies.

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7 APPENDIX

Table 3. Descriptive statistics of independent variables

	TPACK (composite)	Agency (composite)	AVSU (composite)	Work experience	Teaching experience
N (valid)	47	59	46	59	59
Missing	59	47	60	47	47
Mean	3.70	5.58	3.99	16.50	8.63
SD	0.50	0.64	0.92	9.33	6.60
Minimum	2.57	4.46	1.25	0.00	0.00
Maximum	4.86	7.00	5.00	37	30

Note: While TPACK and AVSU was measured a five-point Likert scale (1 = strongly disagree to 5 = strongly agree) the Teacher Agency was measured a seven-point Likert scale (1 = strongly disagree to 7 = strongly agree, experience was measured in years).

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