International Journal of Evaluation and Research in Education (IJERE)
Vol. 15, No. 5, October 2026, pp. 4306~4320
ISSN: 2252-8822, DOI: 10.11591/ijere.v15i5.39294

3D modeling knowledge, perceived usefulness, and intention to use Shapr3D in vocational teacher education

Basyirun[1], Andri Setiyawan[2,3], Soeharto[3,4,5], Daniel Jarvis[6], Jan Vaněk[7], Zsolt Lavicza[3]
[1]Vocational Education, Postgraduate School, Universitas Negeri Semarang, Semarang, Indonesia
[2]Department of Mechanical Engineering, Faculty of Engineering, Universitas Negeri Semarang, Semarang, Indonesia
[3]Linz School of Education, Johannes Kepler University Linz, Linz, Austria
[4]Research Center of Educational Technologies, Azerbaijan State University of Economic (UNEC), Baku, Azerbaijan
[5]National Research and Innovation Agency (BRIN), Jakarta, Indonesia
[6]Schulich School of Education, Nipissing University, Ontario, Canada
[7]Department of Technical and Vocational Education, Faculty of Education, University of Ostrava, Ostrava, Czech Republic

Article Info

Article history:

Received Mar 4, 2026
Revised May 11, 2026
Accepted Aug 5, 2026

Keywords:

3D printing
3DMP
Behavioral intention
Engineering education
Perceived usefulness
Teacher education
Vocational education

ABSTRACT

Although 3D modeling is increasingly promoted in technical and vocational education and training (TVET) teacher education, evidence on vocational pre-service teachers' 3D modeling knowledge remains limited. Evidence on how this knowledge shapes their intention to use the tools in future teaching is also scarce. This study examined the relationships among 3D modeling knowledge (K3DM), perceived usefulness (PU), and behavioral intention (BI) to use the technology in vocational teacher education. Survey data were collected through purposive sampling from 157 vocational pre-service teachers across 13 teacher education institutions in Indonesia. The data were analyzed using descriptive statistics and covariance-based structural equation modeling (CB-SEM). Confirmatory factor analysis (CFA) indicated acceptable measurement properties, Chi-square (χ^2) (101)=191.081, p<0.001, comparative fit index (CFI)=0.966, Tucker–Lewis index (TLI)=0.960, root mean square error of approximation (RMSEA)=0.075, and standardized root mean square residual (SRMR)=0.036. The structural model also showed good fit. The results revealed that K3DM positively predicted both PU and BI. However, PU did not significantly predict BI, and the indirect effect of K3DM on BI through PU was not supported. These findings reveal that in vocational teacher education, strengthening pre-service teachers' modeling competence and task readiness is more important than emphasizing PU alone. This is particularly important when preparing them to integrate 3D modeling into instruction. The study highlights the educational significance of embedding hands-on 3D modeling experiences into teacher preparation programs to better equip future vocational teachers for technology-integrated instruction.

Corresponding Author:

Basyirun
Vocational Education, Postgraduate School, Universitas Negeri Semarang
Semarang-50229, Indonesia
Email: basyirun@mail.unnes.ac.id

1. INTRODUCTION

Technical and vocational education and training (TVET) is widely recognized as a strategic sector for strengthening human capital, supporting inclusive socio-economic development, and reducing unemployment [1], [2]. In many developing countries, vocational education is positioned as a practical pathway to mitigate skills mismatches that constrain growth [3]–[5]. At the same time, rapid technological change and Industry 4.0 pressures require vocational education to continuously update curricula so learners gain relevant digital and technological competencies [6]. To respond to digitalization and Industry 4.0 demands, reinforcing the strategic importance of strengthening technology-related competencies in vocational pathways [7]. Accordingly, strengthening TVET is increasingly framed as an urgent global priority for both economic resilience and workforce transformation.

Preparing future vocational teachers requires not only pedagogical knowledge but also technical skills aligned with contemporary industrial tools and workflows [8]. One important technical capability is 3D modeling, which supports engineering drawing, visualization, and design-based learning across many vocational fields [9]. Evidence from teacher-education-oriented studies reveals that engaging pre-service teachers in 3D modeling and related digital fabrication activities can strengthen technical understanding and learning design capacity [10]. However, studies on implementing Shapr3D as computer-aided design (CAD) software in vocational pre-service teacher education remain limited [11].

Perceived usefulness (PU) and behavioral intention (BI) are commonly theorized as key psychological mechanisms in technology acceptance research. In the technology acceptance model (TAM), PU reflects the extent to which users believe a system enhances performance, and it is expected to increase intention to use the system [12]. Relatedly, in broader acceptance frameworks such as unified theory of acceptance and use of technology (UTAUT), users' performance-related expectations are proposed as important predictors of BI [13]. Usefulness beliefs help explain whether teachers and pre-service teachers intend to adopt new tools for learning and instruction. Therefore, linking 3D modeling knowledge with PU and intention offers a grounded way to understand technology uptake in vocational teacher education.

Prior research has rarely examined an integrated pathway model that connects 3D modeling knowledge (K3DM), PU, and intention within vocational pre-service teacher education. This limitation is particularly salient for Shapr3D as CAD software, as existing Shapr3D-related research is still emerging and has not yet been widely integrated into TAM in vocational teacher education settings [14]. In addition, technology acceptance theory suggests usefulness should matter for intention, yet the strength of this mechanism may vary by context and by the extent to which competence directly drives readiness to adopt. To address this gap, the present study examined the relationships among K3DM, PU, and BI to use the technology in vocational teacher education. This study provides a new contribution by exploring how K3DM, PU, and BI relate to one another within a single structural model in a Shapr3D-based vocational teacher education setting. It extends prior research by focusing on domain-specific competence as a driver of technology adoption among vocational pre-service teachers rather than examining general technology acceptance alone. Guided by this rationale, the study formulates the following research questions:

- RQ1: What are pre-service teachers' perceived levels of K3DM, PU, and BI to use the technology in education?
- RQ2: To what extent does K3DM predict PU and BI in the structural model?
- RQ3: Does PU mediate the relationship between K3DM and BI?

In the following section, we shall summarize the literature relevant to the current research study and present our research model and a series of hypotheses regarding potential findings.

2. LITERATURE REVIEW

2.1. 3D modeling in engineering drawing

Vocational education is increasingly expected to prepare learners for technology-rich workplaces that require advanced digital competencies [15]. Within this shift, 3D modeling is commonly positioned as a foundational skill that supports digital design, prototyping, and communication of technical ideas [16]. 3D modeling knowledge supports design and communication tasks in technical and engineering work [17]. Empirical work in technology and vocational-related education shows that 3D modeling activities can strengthen learners' design thinking and spatial reasoning through iterative visualization and refinement. Evidence from technical and vocational contexts also suggests that combining 3D modeling with 3D printing can enhance hands-on learning by linking abstract designs to tangible outputs [18]. Collectively, these studies indicate that 3D modeling is not only a software-related skill but also a pedagogical pathway for developing applied technical reasoning within the vocational education framework.

In vocational teacher education, pre-service teachers' capability to use and teach digital design tools is frequently framed as a prerequisite for effective technology integration in workshops and classrooms. Engineering drawing and related subjects particularly benefit from 3D modeling because it supports the transition between 3D representations and conventional technical documentation practices [10]. Recent work in technology-related education also highlights that structured modeling activities can foster learners' conceptual understanding and representation competence [19], which are relevant to future teachers who must scaffold students' modeling processes. However, the current evidence base tends to emphasize broad

CAD or modeling ecosystems rather than systematically examining specific emerging platforms used in training contexts. Accordingly, this study is positioned to extend prior TVET-focused modeling research by examining K3DM developed through Shapr3D and linking it to downstream acceptance-related outcomes.

2.2. Perceived technology usefulness in education

In the TAM, PU is theorized to influence BI, typically operating alongside perceived ease of use as key cognitive determinants of adoption [12]. In broader acceptance frameworks, PU aligns conceptually with performance expectancy, which similarly predicts intention when users expect meaningful gains from using a technology [13]. Across technology acceptance studies, PU is generally one of the most robust predictors in TAM-based models [20], although effect sizes vary by population and context. In educational settings, usefulness judgments often reflect whether a tool is seen as improving learning effectiveness, teaching efficiency, or instructional quality [21].

In teacher education contexts, PU is especially salient because teachers evaluate technologies not only for personal productivity but also for pedagogical value and classroom feasibility. For modeling-oriented tools, usefulness perceptions can be shaped by how well the tool supports visualization, design iteration, and communication of technical ideas, which are core aims in engineering drawing and vocational learning [22], [23]. When learners already possess strong domain competence, usefulness ratings may become uniformly high, potentially weakening usefulness's ability to explain variation in intention [24]. Conversely, if competence is still developing, PU may play a stronger explanatory role by signaling that the effort invested in learning the tool is worthwhile. Therefore, a key gap remains in clarifying how PU operates specifically for vocational pre-service teachers learning 3D modeling through Shapr3D, where competence and perceived value may interact in distinct ways.

2.3. Behavioral intention of technology use

The technology acceptance research as a proximal determinant of actual use, capturing an individual's readiness to adopt and enact a technology-related behavior [25]. In TAM, intention is directly predicted by PU, reflecting the assumption that users adopt tools they expect to be beneficial [12]. In UTAUT, BI is similarly explained by performance expectancy, effort expectancy, social influence, and facilitating conditions, depending on the model specification and context [13]. In education, intention is commonly interpreted as teachers' willingness to integrate technology into planning and instruction, a critical precursor to classroom-level implementation [19]. Empirical syntheses indicate that intention is influenced not only by PU but also by capability-related beliefs and contextual supports, which can alter the strength of the usefulness–intention link.

For vocational pre-service teachers, intention to use 3D modeling tools may be shaped by the extent to which modeling knowledge translates into confidence and perceived instructional feasibility. Technical competence can function as a direct driver of intention when users feel able to execute tasks [26]. At the same time, modeling- and prototyping-oriented learning environments may heighten intention when learners experience clear performance benefits from the technology [27]. Evidence from technical and vocational learning indicates that design-to-production experiences can strengthen motivation to continue using such tools, suggesting that intention may grow from hands-on success experiences [28]. Nevertheless, limited research has explicitly tested an integrated pathway linking Shapr3D-based K3DM, PU, and BI among vocational pre-service teachers, a specific empirical gap this study addresses.

2.4. Research model and hypotheses

The proposed research model conceptualizes K3DM as a core capability that shapes vocational pre-service teachers' beliefs and intentions regarding the use of 3D modeling technology for teaching and learning. From an adoption-theory perspective, PU serves as a proximal cognitive belief that explains why individuals develop a BI to use a technology [12]. Prior research in teacher education and educational technology likewise indicates that PU can predict intention, including among pre-service teachers, although the magnitude of this relationship may vary across contexts and depending on other predictors included in the model [29]. At the same time, competence-related factors such as knowledge and skill can influence adoption by strengthening individuals' perceived capability to successfully perform required tasks, thereby supporting readiness to act [30]. Accordingly, the model specifies K3DM as an antecedent of both PU and BI, and tests whether PU serves as an explanatory pathway through which K3DM translates into intention to use 3D modeling technology in educational practice, as shown in Figure 1. Based on the rationale, the study hypothesizes that: i) K3DM positively predicts PU of Shapr3D-based 3D modeling for learning and teaching (H1); ii) PU positively predicts BI to use the technology in education (H2); iii) K3DM positively predicts BI to use the technology in education (H3); and iv) PU mediates the relationship between K3DM and BI (H4).

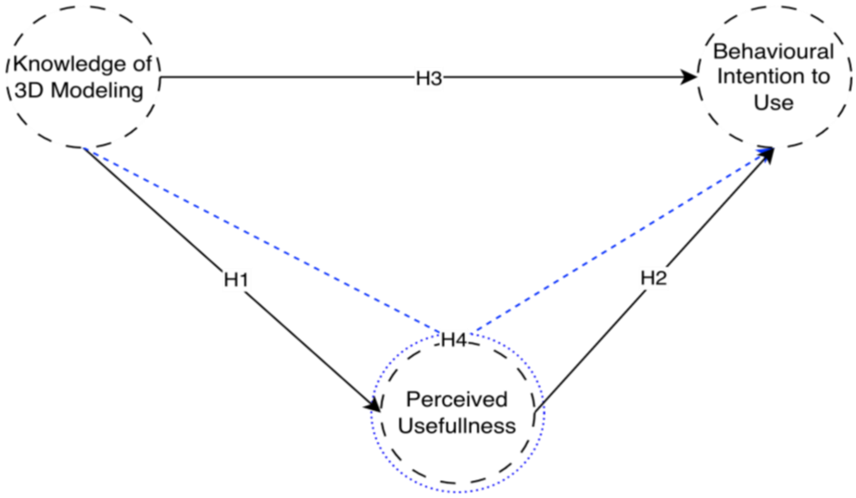

Figure 1. Proposed research model of the study

3. METHOD
3.1. Participants

This study employed a quantitative survey design. Participants were pre-service vocational teachers in Indonesia who were purposively selected for a Shapr3D-based 3D modeling training. A purposive sampling strategy was used because the study required respondents with direct experience of the focal technology and training context. A total of 157 respondents completed the survey, with a mean age of 20.99 years. This sample size was considered acceptable for structural equation modeling (SEM), particularly given the relatively parsimonious model with three latent constructs and 16 observed indicators [31]. Prior guidance indicates that samples around 100 can be sufficient in well-measured models [32]. Table 1 summarizes their demographic characteristics, including gender, year of study, vocational subject area, and place of residence. Participants were drawn from 13 teacher education institutions and multiple vocational subject areas, supporting the sample's relevance to vocational pre-service teacher education in Indonesia. Nevertheless, the findings should be generalized with caution.

Table 1. Participant demographics

Variables	Category	Frequency (n)	Percentage (%)
Gender	Male	132	84
	Female	25	16
Year of study	1st year	27	17
	2nd year	42	27
	3rd year	17	11
	4th year	71	45
Vocational subject area	Automotive engineering	76	48
	Electrical engineering	9	6
	Machining engineering	72	46
Residence	Rural	104	66
	Urban	53	34

3.2. Procedures

This study received ethical approval from the Faculty of Engineering, Universitas Negeri Semarang, Indonesia (Approval No. B/5181/UN37.1.5/KP.15/2025). The study was implemented as part of a vocational teacher development program (VTDP) focused on 3D modeling, specifically using Shapr3D. The program was delivered in a structured hybrid format, combining on-site training sessions with online learning activities.

During the program, participants were introduced to Shapr3D as a new 3D modeling tool. Shapr3D was selected because it offers accessible educational licensing, a range of visualization features, and support for collaborative teamwork. In addition, its compatibility with tablet-based workflows (e.g., an iPad) enables flexible modeling practices aligned with contemporary digital learning environments. The training was delivered in four sessions (a total of 32 hours) focusing on 3D modeling for engineering drawing using Shapr3D. Across the sessions, participants received guided demonstrations and hands-on practice on core modeling operations and workflow strategies relevant to engineering drawing tasks. As the main performance task, participants designed a 3D model intended as learning media for an orthographic projection assignment, and translated it into standard multi-view representations. The training outputs, therefore, included a completed Shapr3D model file and an orthographic projection task artifact aligned with the instructional objectives of engineering drawing. Figure 2 shows participants engaged in 3D modeling using Shapr3D to create an orthographic projection.

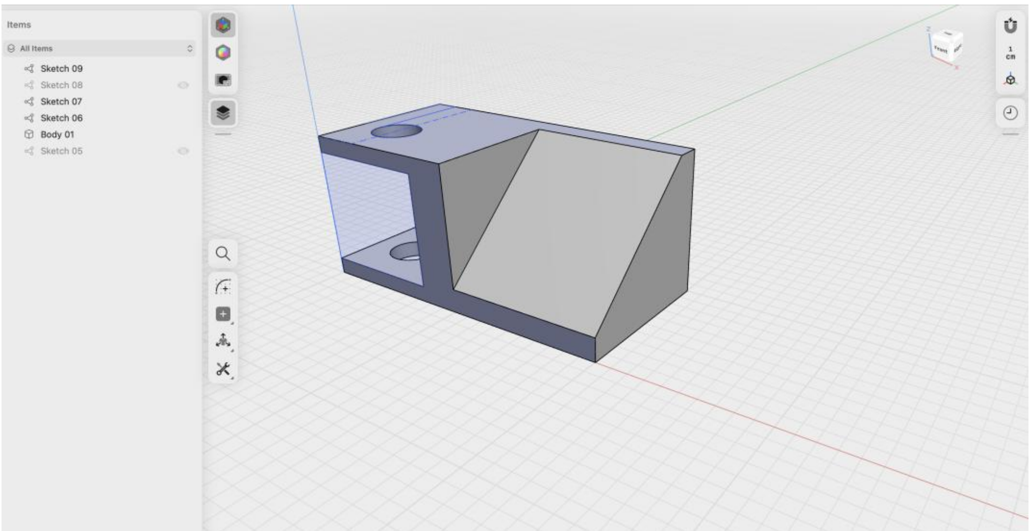

Figure 2. Sample of a 3D orthographic projection model created by participants

3.3. Instruments

Data for this study were collected using a self-administered online survey distributed via Google Forms. The survey consisted of three sections. The first section included an informed consent statement confirming that participants agreed to participate in the study and that their participation was voluntary. The second section gathered participants' demographic information. The third section assessed perceptions of K3DM, PU, and BI. All items were rated on a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). The complete questionnaire is available in Table 2.

K3DM was defined and operationalized as pre-service teachers' self-perceived competence in core Shapr3D modeling workflows required for engineering drawing tasks, including creating models, saving or exporting designs, and generating orthographic projection working drawings. This approach is consistent with prior work that measures 3D modeling capability through perceived competence in modeling operations and task performance, and with studies that positioning 3DMP knowledge as a relevant foundation for technology-related outcomes in learning contexts [33], [34].

Table 2. Questionnaire of the study

Variables	Item (code)	Questions
K3DM	K3DM1	I understand how to create 3D designs using Shapr3D.
	K3DM2	I understand how to save 3D modeling designs in various formats using Shapr3D.
	K3DM3	I know the basic ways to produce technical drawings using Shapr3D software.
	K3DM4	I know how to create blueprint/working drawings by converting 3D models into 2D using Shapr3D.
	K3DM5	I know the procedures for creating orthographic projection working drawings using Shapr3D software.
PU	PU1	Digital drawing with Shapr3D will improve my learning performance.
	PU2	Digital drawing with Shapr3D will increase my academic productivity.
	PU3	Digital drawing with Shapr3D can make it easier for me to learn course material.
	PU4	Digital drawing with Shapr3D will enhance learning effectiveness.
	PU5	I find that digital drawing with Shapr3D is very useful.
BI	BI1	I intend to use Shapr3D-based 3D modeling activities in my teaching in the future.
	BI2	I plan to integrate Shapr3D when teaching 3D modeling and technical drawing topics.
	BI3	I expect to design learning tasks that use Shapr3D to develop students' 3D modeling skills.
	BI4	If given the opportunity, I will use Shapr3D to support students' learning about 3D models and their representations.
	BI5	I am likely to rely on Shapr3D to help students visualize and understand 3D objects in learning activities.
	BI6	I will frequently use Shapr3D when preparing 3D modeling instructional materials in the future.

Moreover, the survey items were developed by adapting validated measures from previous studies to fit the context of Shapr3D-based 3D modeling in engineering drawing. Minor wording modifications were made to ensure contextual relevance for vocational pre-service teachers, while retaining the original construct meanings. PU in this study was measured using five items adapted and contextualized from the TAM-based questionnaire. Additionally, the BI items were adapted from prior technology adoption frameworks, particularly the TAM and the UTAUT. To ensure linguistic accuracy and conceptual equivalence, the instrument was translated into Bahasa Indonesia through a forward–backward translation process. The translated version was then evaluated by three experts in educational measurement, engineering education, and vocational teacher training to examine item clarity, contextual appropriateness, and content relevance. This development and review process was undertaken to strengthen the instrument's content validity and contextual suitability prior to data collection.

3.4. Data analysis

Quantitative analyses were conducted using IBM SPSS Statistics (version 30) and Mplus (version 9). Descriptive statistics were computed to summarize participants' demographic characteristics, including age, gender, vocational subject area, year of study, and place of residence. In addition, SEM was carried out in Mplus 9 to examine both the measurement and structural components of the proposed model. A two-step SEM procedure was applied. First, confirmatory factor analysis (CFA) was conducted to evaluate the measurement model, including indicator loadings, construct validity, and reliability. Second, the structural model was tested to examine the hypothesized relationships among K3DM, PU, and BI. Overall model fit was assessed using commonly recommended criteria: comparative fit index (CFI) and Tucker–Lewis index (TLI)$\geq$0.90, root mean square error of approximation (RMSEA)$\leq$0.08, and standardized root mean square residual (SRMR)$\leq$0.08 [35]. Internal consistency reliability was evaluated using Cronbach's alpha, with values of 0.70 or higher interpreted as acceptable [36]. Convergent validity and construct reliability were further assessed using composite reliability (CR) and average variance extracted (AVE), with CR$\geq$0.70 and AVE$\geq$0.50 indicating adequate reliability and convergent validity [36].

4. RESULTS

The following sections report the results in relation to the research questions. First, they present participants' perceived levels of K3DM, PU, and BI. Second, they report the assessment of the measurement model. Third, they present the evidence of validity and reliability. Fourth, they report the assessment of the structural model. The results are summarized in tables and figures with accompanying explanations.

4.1. Pre-service vocational teachers' perceived levels in K3DM, PU, and BI

The descriptive statistics indicate consistently high perceptions across all three constructs, as shown in Table 3. The mean score for K3DM was M=6.01 (SD=1.037), suggesting that vocational pre-service teachers generally perceived themselves as knowledgeable and capable in 3D modeling. PU showed the highest average rating, M=6.24 (SD=0.915), indicating that most participants viewed the technology as highly useful for educational purposes. The relatively lower standard deviation (SD) for PU also suggests greater agreement among participants about the technology's value. BI was similarly high, M=6.05 (SD=1.014), suggesting that participants reported a strong intention to use the technology in educational contexts. Overall, the combination of high means and moderate variability suggests that participants held positive perceptions of 3D modeling knowledge, usefulness, and adoption intention, with PU being the most consistently endorsed dimension.

Table 3. Descriptive statistics of perceived K3DM, PU, and BI

Variables	Mean	SD
K3DM	6.01	1.037
PU	6.24	0.915
BI	6.05	1.014

4.2. Measurement model

The assessment of the three-factor CFA measurement model showed acceptable-to-good overall fit for the full sample (N=157), with Chi-square (χ^2) (101)=191.081, p<0.001, CFI=0.966, TLI=0.960, RMSEA=0.075 (90% CI [0.059, 0.092]), and SRMR=0.036. All indicators loaded positively and significantly on their intended factors (p<0.001), and standardized loadings were strong overall, ranging from 0.825–0.932 for K3DM, 0.899–0.946 for PU, and 0.688–0.936 for BI (with BI6 the lowest at 0.688), supporting convergent validity. Item explained variance (R^2) was largely substantial (K3DM: 0.680–0.868; PU: 0.808–0.894; BI: 0.473–0.877), indicating that the latent factors accounted for a meaningful proportion of variance in the observed indicators. Latent correlations were positive and significant, with K3DM–PU r=0.634 ($p<0.001$), BI–K3DM r=0.388 ($p<0.001$), and BI–PU r=0.285 ($p<0.001$), suggesting related but empirically distinguishable constructs and supporting the adequacy of the measurement model for subsequent structural analyses. Standardized factor loadings (SFL) and the measurement model are presented in Figure 3.

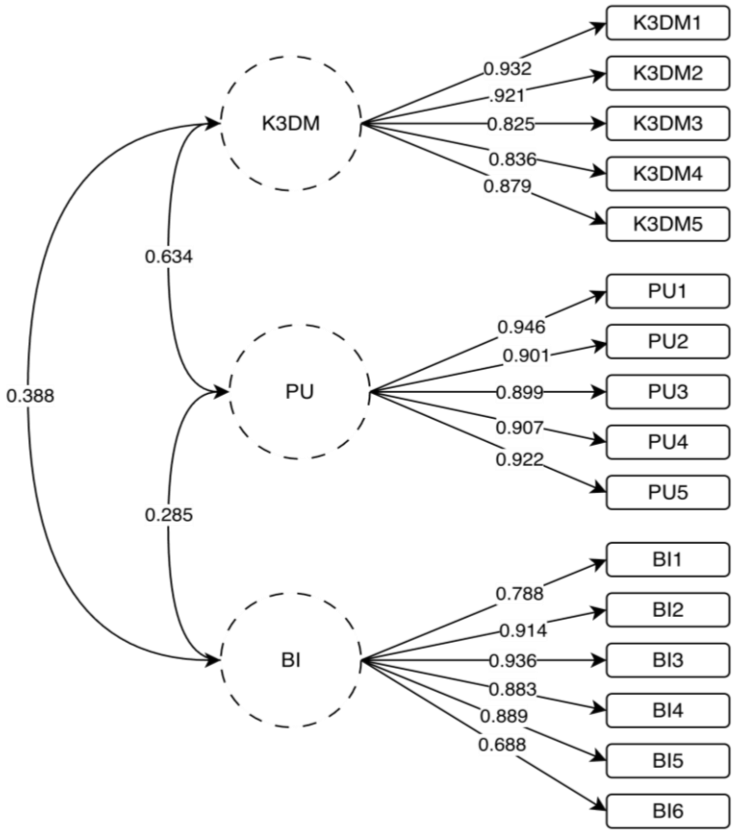

Figure 3. Measurement model of K3DM, PU, and BI

4.3. Validity and reliability criteria

The validity and reliability of the study constructs were evaluated using SFL to assess construct validity and Cronbach's alpha (α) to examine internal consistency. Consistent with previous study [37], SFL values above 0.50 indicate adequate convergent validity at the item level. As shown in Table 4, all indicators for the three constructs, K3DM, PU, and BI, exceeded the 0.50 threshold, supporting satisfactory construct validity. For K3DM, standardized loadings ranged from 0.825 to 0.932, indicating strong convergence of the five knowledge items on the latent construct. PU items showed very strong loadings overall, ranging from 0.899 to 0.946, suggesting that the PU indicators consistently capture the same underlying perception. The BI construct also demonstrated generally strong item validity, with loadings ranging from 0.688 to 0.936; although BI6 was the weakest indicator (0.688), it still met the recommended minimum and therefore remains acceptable.

Internal consistency reliability was assessed using Cronbach's alpha, with values≥0.70 commonly interpreted as good reliability [36], [38]. The results indicate excellent reliability for all constructs: K3DM (α=0.945), PU (α=0.962), and BI (α=0.939). These high alpha coefficients suggest that the items within each construct are highly consistent and measure the same underlying concept. Overall, the combined evidence from strong SFL and excellent Cronbach's alpha values indicates that the measurement model demonstrates robust construct validity and internal consistency, providing a solid foundation for subsequent structural analyses.

Table 4. Construct, items, SFL range, α, CR, and AVE values based on dimensions in the structural model

Variables	Item	SFL	α	CR	AVE
K3DM			0.945	0.945	0.774
	K3DM1	0.932			
	K3DM2	0.921			
	K3DM3	0.825			
	K3DM4	0.836			
	K3DM5	0.879			
PU			0.962	0.963	0.838
	PU1	0.946			
	PU2	0.901			
	PU3	0.899			
	PU4	0.907			
	PU5	0.922			
BI			0.939	0.942	0.732
	BI1	0.788			
	BI2	0.914			
	BI3	0.936			
	BI4	0.883			
	BI5	0.899			
	BI6	0.688			

Note: α=Cronbach's alpha (internal consistency)

4.4. Structural model assessment

The structural analysis indicates that the model is primarily driven by K3DM's effects on the downstream variables, as shown in Figure 4. Two of the four hypothesized effects were supported, showing a consistent pattern in which K3DM functions as the key explanatory construct. Specifically, K3DM had a strong positive effect on PU (H1: $\beta=0.584$, $p<0.001$), suggesting that higher competence/knowledge in 3D modeling is associated with stronger judgments that the technology or approach is useful. In addition, K3DM showed a significant direct positive effect on BI (H3: $\beta=0.310$, $p=0.001$), suggesting that participants' technical knowledge may translate into an intention to use the related system or approach, even without relying on intermediate attitudinal mechanisms. The majority of supported paths (H1 and H3) provide a coherent theoretical logic: greater domain knowledge likely increases users' confidence, perceived feasibility, and readiness to adopt the practice, thereby elevating both PU and BI through a more "capability-driven" adoption process.

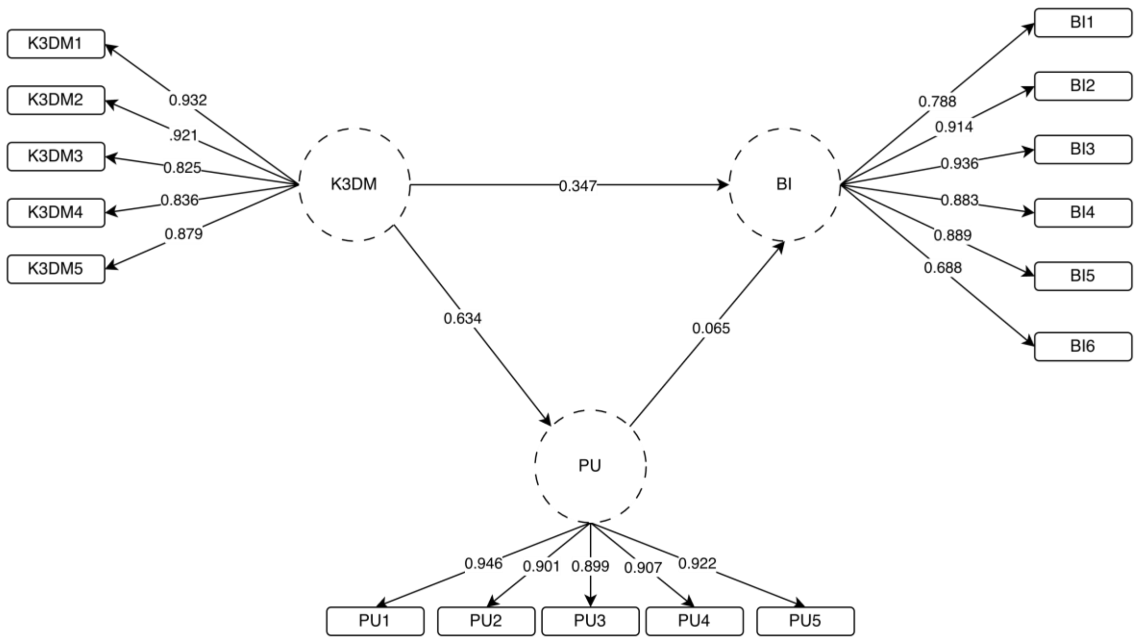

Figure 4. The structural model of this study

In contrast, the paths involving PU as a mediator were rejected, as shown in Table 5. The direct effect of PU on BI was not significant (H2: β=0.063, p=0.528), and consequently the indirect effect of K3DM on BI through PU was also not supported (H4: β=0.037, p=0.529). A plausible explanation is that, in this sample, intention is shaped more by competence and familiarity (K3DM) than by evaluative beliefs about PU, meaning that usefulness perceptions may be uniformly high and therefore provide limited variance to predict BI. Furthermore, another possibility is that BI is influenced by omitted adoption factors, which could suppress the unique predictive contribution of PU once K3DM is included. Overall, the rejected paths suggest that while participants recognize usefulness, this recognition alone does not reliably translate into intention in this model; instead, intention appears to be explained more directly by participants' underlying 3D modeling knowledge.

Table 5. Path analysis and hypothesis testing

Hypothesis	Structural path	Estimate (β)	S.E.	Est./S.E.	p-value	Conclusion
Direct effect						
H1	K3DM→PU (+)	0.584	0.065	9.046	0.000***	Supported
H2	PU→BI (+)	0.063	0.099	0.631	0.528	Rejected
H3	K3DM→BI (+)	0.31	0.095	3.277	0.001**	Supported
Indirect effect						
H4	K3DM→PU→BI (+)	0.037	0.058	0.63	0.529	Rejected

Note: estimate (β)=standardized path coefficient; S.E.=standard error; Est./S.E.=critical ratio (z-value) obtained by dividing the estimate by its standard error; p-value=statistical significance level (two-tailed).

5. DISCUSSION

The present study investigated the relationships among K3DM, PU, and BI to use Shapr3D-based 3D modeling in vocational teacher education. It also described pre-service teachers' perceived levels of K3DM, PU, and BI as an initial indicator of their readiness to adopt the technology. In what follows, the findings will be discussed in relation to prior research on K3DM, PU, and technology use intention in educational settings. The evidence offers a rationale for targeted interventions and provides an updated perspective on integrating Shapr3D into 3D modeling instruction for vocational pre-service teachers. The research conclude by highlighting the implications for theory and practice, along with study limitations and directions for future research.

5.1. Pre-service teachers' perceived levels of K3DM, PU, and BI

Participants expressed uniformly positive perceptions across K3DM, PU, and BI. This result suggests a strong readiness to engage in Shapr3D-supported modeling tasks in educational settings. This pattern is plausible in a structured training context, where guided practice and timely feedback can help participants consolidate procedural competence and translate early mastery experiences into favorable appraisals of value and continued use [26]. In such conditions, attitudes and intentions often rise together because capability is being built alongside clear task relevance [18].

The construct with the highest mean was PU, and its relatively smaller dispersion indicates greater agreement among participants about the value of Shapr3D for learning and teaching. In TAM terms, high PU reflects a shared belief that the tool improves performance and learning effectiveness, which is commonly observed when a technology is perceived as directly supporting task goals [12]. At the same time, high mean levels can also imply restricted variance, which may reduce the predictive power of PU for downstream outcomes in structural models [37]. From a TVET perspective, strong endorsements of usefulness and intention are encouraging, as digital competence is increasingly positioned as a key requirement for vocational pathways under Industry 4.0 pressures. This result indicates a favorable baseline for adoption, with the caveat that very positive ratings may partly reflect self-selection into the training program.

5.2. The relationship between K3DM, PU, and BI in the structural model and the mediation effect

The structural results indicate that 3D modeling knowledge is the central explanatory factor in the proposed pathway. Specifically, stronger 3D modeling knowledge was associated with higher PU of Shapr3D for educational purposes, suggesting that participants who feel more competent in modeling workflows are better able to recognize how the tool can enhance learning and teaching outcomes. This pattern is theoretically consistent with the view that mastery experiences and capability beliefs shape how individuals evaluate task-related tools, since competent users can more readily anticipate performance gains and instructional value [30], [38], [39]. Evidence from teacher-focused technology acceptance research also suggests that competence-related antecedents often function as enabling conditions that strengthen favorable appraisals and reduce uncertainty about implementation in authentic instructional contexts [40], [41]. The findings support a capability-to-belief link, in which modeling knowledge serves as an important foundation for perceiving Shapr3D as useful within vocational teacher education.

In addition, 3D modeling knowledge showed a direct positive association with BI, even when PU was included in the model. This finding suggests that 3D modeling competence directly drives technology adoption by enhancing users' confidence, perceived feasibility, and readiness to implement Shapr3D in authentic instructional contexts. This pattern is theoretically plausible because stronger perceived capability and control can translate into greater readiness to act and lower implementation uncertainty, which are central determinants of intention in teacher technology adoption research [42]. Building on evidence that learners' knowledge can shape BI through intervening psychological processes [43], our study examines whether 3D modeling knowledge predicts technology use intention among vocational pre-service teachers via PU. It also aligns with broader adoption frameworks suggesting that intention is shaped not only by evaluative beliefs such as usefulness, but also by feasibility-related conditions and perceived control that make technology use feel manageable in authentic instructional contexts [44], [45]. In contrast, PU did not uniquely predict BI in this model, which is consistent with evidence that the strength of TAM pathways varies across educational settings and model specifications, and that competence-related predictors can absorb variance that might otherwise be attributed to usefulness [19], [41]. In competence-rich learning environments, PU may not always translate into BI. Once users have developed sufficient task competence, intention is more likely to be shaped by confidence, familiarity, and readiness to apply the technology than by usefulness judgments alone. The supported paths from 3D modeling knowledge to PU and BI point to a capability-driven adoption pattern, in which growing competence simultaneously strengthens value appraisals and willingness to continue use.

Compared with much of the existing literature, this study found that the indirect effect of 3D modeling knowledge on intention through PU was not significant for Shapr3D adoption. In terms of PU, prior studies commonly report that PU has a direct, positive effect on intention to use CAD tools [46]. Notwithstanding, a few studies have shown that PU is not always a significant predictor of BI in CAD or building information modeling (BIM) related software adoption contexts [47], [48]. Wang *et al.* [49] argue that when PU does not significantly predict BI, it may signal that reluctance toward adopting new technologies has become less salient than in earlier phases of technology diffusion. Consistent with this interpretation, PU has also been reported as a comparatively weak determinant of students' intentions to use YouTube for procedural learning [50]. Furthermore, drawing 3D models using Shapr3D was the participants' first experience. In this situation, participants are still in an initial exploration phase, where judgments about "usefulness" tend to be tentative and impression-based, because they have not yet had sufficient opportunities to verify whether the software genuinely improves their teaching workflow, saves time, or enhances learning outcomes in real classroom settings. In such circumstances, when the use is still trial-oriented and capability-building, BI is often shaped more by immediate factors, such as confidence in performing the tasks, perceived difficulty, and whether they feel able to reproduce the same results independently, rather than by PU as a general belief. As a result, even if participants agree that Shapr3D is useful in principle, that agreement may not translate into a stronger intention to continue using it until usefulness is confirmed through repeated practice and authentic instructional implementation. Thus, future research should continue, particularly through follow-up measurements after participants have gained more experience and had the chance to integrate Shapr3D into actual teaching activities.

Teacher education programs can implement these findings by organizing 3D modeling instruction in stages, from basic operations to orthographic projection tasks and lesson design. They can also include microteaching and project-based assignments that help pre-service teachers apply Shapr3D in classroom-related tasks. In addition, formative feedback, peer discussion, and revision opportunities may strengthen both technical mastery and readiness to use the technology in future teaching. For teacher education institutions, this means that Shapr3D training should not be treated as a stand-alone software workshop, but as an integrated component of vocational pedagogy. The development programs connect digital modeling competence with instructional design and classroom implementation.

5.3. Theoretical contribution

This study extends the TAM by showing that technology adoption in vocational teacher education is not driven only by PU, but also by domain-specific technical competence. In the Shapr3D-based training context, 3D modeling knowledge directly predicted both PU and BI, whereas PU did not significantly predict intention. This finding refines TAM by identifying a capability-driven adoption pathway, where pre-service teachers' readiness to use digital modeling tools depends strongly on their ability to perform authentic modeling tasks. Vocational technology acceptance should account for users' technical knowledge, task readiness, and instructional application capacity [12], [19], [30], [40], [42].

5.4. Implications

The findings offer several implications for vocational teacher education practice. First, the consistently high perceived levels of 3D modeling knowledge, PU, and BI suggest that structured Shapr3D-based training can be positioned as an effective entry point for strengthening pre-service teachers' readiness to adopt 3D modeling in teaching. Vocational teacher education programs should therefore design training activities that prioritize hands-on modeling practice, authentic problem-solving tasks, and repeated opportunities to apply 3D modeling in instructional contexts. Program designers may therefore prioritize hands-on modeling tasks that directly connect technical skills to authentic vocational teaching scenarios, such as producing 3D representations for orthographic projection, interpreting engineering drawings, or product prototyping. Because the supported direct pathway from 3D modeling knowledge to BI indicates a capability-driven adoption pattern, instructional designs should emphasize mastery experiences, progressive task difficulty, and frequent feedback to build confidence and sustained engagement. In addition, training should be structured to help pre-service teachers move from technical operation toward pedagogical application. For example, this can be achieved by integrating lesson design tasks, classroom-oriented projects, and reflection on how 3D modeling can support student learning. In addition, teacher educators can embed collaborative modeling workflows and classroom-oriented assignments to help pre-service teachers translate individual competence into instructional practice. Finally, these results support integrating Shapr3D not only as software training but also as a pedagogical tool, with learning outcomes that include both technical proficiency and instructional planning skills aligned with vocational education needs.

From a theoretical and research perspective, the results imply that technology acceptance in TVET teacher education may not always operate primarily through PU, especially when users already report high usefulness beliefs. The non-significant indirect effect suggests that competence-related variables, such as domain knowledge, can function as a more proximal determinant of intention in contexts where PU is relatively homogeneous or where intention is shaped by other adoption factors not included in the current model. Future studies should therefore extend the model by incorporating constructs that capture effort or usability beliefs, social influence, facilitating conditions, and self-efficacy to clarify when and why usefulness translates into intention for vocational pre-service teachers. Methodologically, the unequal gender group sizes in the multigroup analysis highlight the need for more balanced samples or alternative analytic strategies before drawing strong conclusions about gender differences. More broadly, the study positions Shapr3D-based 3D modeling knowledge as a meaningful capability construct in vocational education contexts and encourages further research to test whether strengthening this capability also predicts downstream outcomes such as instructional quality, classroom implementation, and student learning gains.

5.5. Limitations

This study has several limitations that should be considered when interpreting the findings. First, the sample was obtained through purposive sampling and included only pre-service vocational teachers who participated in Shapr3D training, which may limit generalizability to other populations, institutions, or contexts where exposure to 3D modeling is lower. Second, the data relied on self-administered measures, which are susceptible to common method bias and social desirability effects, and the high mean scores suggest possible ceiling effects that may have reduced variability, particularly for PU, thereby weakening its ability to predict BI. Because all focal constructs were measured using the same self-report instrument at a single point in time, the results should be interpreted with appropriate caution regarding potential common method variance. Third, the cross-sectional design does not allow causal inference or examination of how knowledge, beliefs, and intention develop over time, so longitudinal or pre-post designs would be needed to evaluate change attributable to training. Fourth, the multigroup analysis by gender was constrained by a very small female subsample relative to the male group, which can reduce parameter stability and limit confidence in gender-based comparisons. Finally, the structural model included only three constructs, so other potentially influential adoption determinants, such as perceived ease of use or effort expectancy, facilitating conditions, social influence, and self-efficacy, were not examined and may account for additional variance in BI beyond the pathways tested.

6. CONCLUSION

This study examined how vocational pre-service teachers' K3DM relates to PU and BI to use Shapr3D in educational practice. The findings showed high perceived levels of K3DM, PU, and BI. In the structural model, K3DM significantly predicted both PU and BI, whereas PU did not significantly predict BI and did not mediate the relationship between K3DM and BI. These results suggest a capability-driven adoption pattern, in which early intention to use Shapr3D is shaped more by competence and task readiness than by usefulness beliefs alone. The findings extend technology acceptance research in vocational teacher education by highlighting the role of domain-specific competence as a proximal determinant of intention. In practice, vocational teacher education programs should prioritize structured, hands-on modeling practice, authentic problem-solving tasks, progressive scaffolding, and classroom-oriented design activities to help pre-service teachers translate technical competence into instructional use of 3D modeling technologies.

The use of purposive sampling and the inclusion of only participants who completed the Shapr3D-based training may limit generalizability to other teacher populations and educational contexts. In addition, reliance on self-report measures raises the possibility of common-method bias, social desirability effects, and ceiling effects, particularly for PU. The cross-sectional design also prevents causal inference and does not capture how knowledge, beliefs, and intentions may develop over time. Furthermore, the structural model included only three constructs, and the multigroup comparison by gender was constrained by unequal group sizes. Future research should therefore use longitudinal or pre-post designs, include broader and more balanced samples across institutions and teacher groups, and extend the model by incorporating variables such as perceived ease of use, self-efficacy, facilitating conditions, and social influence. Further studies should also examine whether Shapr3D-based 3D modeling knowledge predicts downstream outcomes such as classroom implementation, instructional quality, and student learning gains.

ACKNOWLEDGMENTS

The authors gratefully acknowledge Universitas Negeri Semarang for facilitating and supporting this collaborative research. We also thank the colleagues and participants who contributed their time and assistance during data collection. Their support was valuable in enabling the successful completion of this study.

FUNDING INFORMATION

This research did not receive funding from public, commercial, or non-profit organizations.

AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Basyirun	✓	✓	✓	✓	✓	✓		✓	✓	✓			✓	✓
Andri Setiyawan		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
Soeharto	✓		✓	✓	✓		✓			✓	✓	✓		
Daniel Jarvis		✓		✓	✓					✓				
Jan Vaněk		✓		✓	✓		✓			✓		✓		
Zsolt Lavicza		✓		✓	✓					✓		✓		

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors state there is no conflict of interest.

INFORMED CONSENT

Permission (consent) was sought from pre-service vocational teachers to realize the research. Participation in the study was voluntary. The data was collected, saved, and analyzed anonymously.

ETHICAL APPROVAL

This study received ethical approval from the Faculty of Engineering, Universitas Negeri Semarang, Indonesia (Approval No. B/5181/UN37.1.5/KP.15/2025).

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author, [B], upon reasonable request.

REFERENCES

[1] A. I. Haji Ali, J. Bungsu, and M. Shahrill, "Experiential learning in action: how design-build-test projects impact VTE students' academic motivation and learning," *Journal of Technical Education and Training*, vol. 17, no. 2, pp. 22–37, Jun. 2025, doi: 10.30880/jtet.2025.17.02.002.

[2] S. McGrath, M. Mulder, J. Papier, and R. Suart, *Handbook of vocational education and training: developments in the changing world of work*. Cham: Springer International Publishing, 2019, doi: 10.1007/978-3-319-94532-3.

[3] G. Brunello and P. Wruuck, "Skill shortages and skill mismatch: a review of the literature," *Journal of Economic Surveys*, vol. 35, no. 4, pp. 1145–1167, Sep. 2021, doi: 10.1111/joes.12424.

[4] L. A. Flórez and L. Gómez, "The impact of skill mismatch on unemployment, informality, and labour turnover," *The Economic and Labour Relations Review*, vol. 35, no. 4, pp. 980–999, Dec. 2024, doi: 10.1017/elr.2024.48.

[5] M. C. Okoye, X. Hui, and A. M. David, "Comparative analysis of technical and vocational education and training systems in China and Sub-Saharan Africa for sustainable development," *Discover Education*, vol. 4, no. 1, p. 535, Dec. 2025, doi: 10.1007/s44217-025-00965-x.

[6] M. Roll and D. Ifenthaler, "Learning Factories 4.0 in technical vocational schools: can they foster competence development?" *Empirical Research in Vocational Education and Training*, vol. 13, no. 1, p. 20, Dec. 2021, doi: 10.1186/s40461-021-00124-0.

[7] M. H. Salleh, S. A. Kadir, R. Jamaluddin, and M. H. M. Puad, "Factors influencing TVET teacher's TPACK competencies in Peninsular Malaysia," *Journal of Technical Education and Training*, vol. 14, no. 3, pp. 105–111, Dec. 2022, doi: 10.30880/jtet.2022.14.03.010.

[8] N. H. Abd Rahman *et al.*, "Governance structures and systemic challenges shaping the future of the technical and vocational education and training (TVET) workforce," *Education + Training*, pp. 1–21, Sep. 2025, doi: 10.1108/ET-11-2024-0508.

[9] M. Pavlova, "TVET as an important factor in country's economic development," *SpringerPlus*, vol. 3, no. S1, p. K3, Dec. 2014, doi: 10.1186/2193-1801-3-S1-K3.

[10] A. I. Benzer and B. Yildiz, "The effect of computer-aided 3D modeling activities on pre-service teachers' spatial abilities and attitudes towards 3D modeling," *Journal of Baltic Science Education*, vol. 18, no. 3, pp. 335–348, Jun. 2019, doi: 10.33225/jbse/19.18.335.

[11] A. Setiyawan, Soeharto, M. Maričić, and Z. Lavicza, "Integrating 3D modeling and printing in automotive component prototyping: perceptions of pre-service vocational teachers," *Technology, Knowledge and Learning*, pp. 1–24, Nov. 2025, doi: 10.1007/s10758-025-09918-7.

[12] F. D. Davis, "Perceived usefulness, perceived ease of use, and user acceptance of information technology," *MIS Quarterly*, vol. 13, no. 3, pp. 319–340, Sep. 1989, doi: 10.2307/249008.

[13] V. Venkatesh, M. G. Morris, G. B. Davis, and F. D. Davis, "User acceptance of information technology: toward a unified view," *MIS Quarterly*, vol. 27, no. 3, pp. 425–478, Sep. 2003, doi: 10.2307/30036540.

[14] A. Setiyawan, L. C. Manggalasari, T. A. Prasetya, T. Towip, and W. Noviansyah, "Development of hydraulic cylinder excavator learning media based on augmented reality with Shapr 3D," in *Journal of Physics: Conference Series*, vol. 2111, no. 1, p. 012008, Nov. 2021, doi: 10.1088/1742-6596/2111/1/012008.

[15] S. Rahmawati, S. Prestridge, A. G. Abdullah, and I. Widiaty, "Unpacking the digital competence challenge in vocational education: a case from Indonesia," *Social Sciences and Humanities Open*, vol. 12, p. 101803, 2025, doi: 10.1016/j.ssaho.2025.101803.

[16] P. Norström and J. Hallström, "Models and modelling in secondary technology and engineering education," *International Journal of Technology and Design Education*, vol. 33, no. 5, pp. 1797–1817, Nov. 2023, doi: 10.1007/s10798-023-09808-y.

[17] A. Šafhalter, S. Glodež, A. Šorgo, and M. P. Virtič, "Development of spatial thinking abilities in engineering 3D modeling course aimed at lower secondary students," *International Journal of Technology and Design Education*, vol. 32, no. 1, pp. 167–184, Mar. 2022, doi: 10.1007/s10798-020-09597-8.

[18] T.-C. Huang and C.-Y. Lin, "From 3D modeling to 3D printing: development of a differentiated spatial ability teaching model," *Telematics and Informatics*, vol. 34, no. 2, pp. 604–613, May 2017, doi: 10.1016/j.tele.2016.10.005.

[19] R. Scherer, F. Siddiq, and J. Tondeur, "The technology acceptance model (TAM): a meta-analytic structural equation modeling approach to explaining teachers' adoption of digital technology in education," *Computers & Education*, vol. 128, pp. 13–35, Jan. 2019, doi: 10.1016/j.compedu.2018.09.009.

[20] M. Mailizar, D. Burg, and S. Maulina, "Examining university students' behavioural intention to use e-learning during the COVID-19 pandemic: an extended TAM model," *Education and Information Technologies*, vol. 26, no. 6, pp. 7057–7077, Nov. 2021, doi: 10.1007/s10639-021-10557-5.

[21] J.-C. Hong *et al.*, "The effect of the 'prediction-observation-quiz-explanation' inquiry-based e-learning model on flow experience in green energy learning," *Computers & Education*, vol. 133, pp. 127–138, May 2019, doi: 10.1016/j.compedu.2019.01.009.

[22] S. H. Masran, M. H. I. Zulkiffle, A. Hasan, S. Y. Yamaguchi, and F. Marian, "The impact of competency-based training towards technical skills mastery among vocational education students," *Journal of Technical Education and Training*, vol. 17, no. 1, pp. 90–98, Apr. 2025, doi: 10.30880/jtet.2025.17.01.007.

[23] B. J. D. Pasion, "Innovation and digitalization strategy in technical education: assessment of an ergonomic universal working table for optimized instructional performance," *Educational Process International Journal*, vol. 18, no. 1, pp. 1–12, 2025, doi: 10.22521/edupij.2025.18.455.

[24] R. K. Singh and B. P. Kushwaha, "An assessment of the behavioral intention of generation Z toward the adoption of digital learning applications," in *IoT and Cloud Computing for Societal Good*, J. K. Verma, D. Saxena, and V. González-Prida, Eds., Cham: Springer International Publishing, 2022, pp. 159–180, doi: 10.1007/978-3-030-73885-3_10.

[25] L. Xue, J. Mahat, and N. Ghazali, "Technology acceptance model in artificial intelligence in education: a meta-analysis," *SAGE Open*, vol. 16, no. 1, pp. 1–23, Jan. 2026, doi: 10.1177/21582440251409441.

[26] J. Lyu, K. Hahn, and H.-J. Lee, "Potential determinants of consumers' intention to purchase 3D printed fashion products," *International Journal of Retail & Distribution Management*, vol. 51, no. 8, pp. 1027–1044, Aug. 2023, doi: 10.1108/IJRDM-09-2021-0437.

[27] V. Gupta, C. Gupta, J. Swacha, and L. Rubalcaba, "Prototyping technology adoption among entrepreneurship and innovation libraries for rural health innovations," *Library Hi Tech*, vol. 42, no. 6, pp. 1760–1795, Nov. 2024, doi: 10.1108/LHT-03-2023-0120.

[28] M. K. Omar, W. M. W. Muhamad, N. Ismail, A. Zakaria, and K. M. Kadir, "Employability skills and career development self-efficacy as indicators for workforce success," *Journal of Technical Education and Training*, vol. 15, no. 3, pp. 118–130, Sep. 2023, doi: 10.30880/jtet.2023.15.03.011.

[29] T. Teo and J. Noyes, "Explaining the intention to use technology among pre-service teachers: a multi-group analysis of the unified theory of acceptance and use of technology," *Interactive Learning Environments*, vol. 22, no. 1, pp. 51–66, Jan. 2014, doi: 10.1080/10494820.2011.641674.

[30] A. Bandura, *Self-efficacy: the exercise of control*. New York, NY: W. H. Freeman, 1997.

[31] J. F. Hair Jr., M. C. Howard, and C. Nitzl, "Assessing measurement model quality in PLS-SEM using confirmatory composite analysis," *Journal of Business Research*, vol. 109, pp. 101–110, Mar. 2020, doi: 10.1016/j.jbusres.2019.11.069.

[32] E. J. Wolf, K. M. Harrington, S. L. Clark, and M. W. Miller, "Sample size requirements for structural equation models," *Educational and Psychological Measurement*, vol. 73, no. 6, pp. 913–934, Dec. 2013, doi: 10.1177/0013164413495237.

[33] B. Anđić, Z. Lavicza, E. Ulbrich, S. Cvjetićanin, F. Petrović, and M. Maričić, "Contribution of 3D modelling and printing to learning in primary schools: a case study with visually impaired students from an inclusive biology classroom," *Journal of Biological Education*, vol. 58, no. 4, pp. 795–811, Aug. 2024, doi: 10.1080/00219266.2022.2118352.

[34] D. Kelly and C. D. Denson, "Reliability and validity for a 3-D modeling self-efficacy scale for pre-college students," *Journal of Technology Studies*, vol. 46, no. 2, pp. 44–51, Apr. 2020, doi: 10.21061/jots.v46i2.a.1.

[35] D. Shi, C. DiStefano, A. Maydeu-Olivares, and T. Lee, "Evaluating SEM model fit with small degrees of freedom," *Multivariate Behavioral Research*, vol. 57, no. 2–3, pp. 179–207, May 2022, doi: 10.1080/00273171.2020.1868965.

[36] K. S. Taber, "The use of Cronbach's alpha when developing and reporting research instruments in science education," *Research in Science Education*, vol. 48, no. 6, pp. 1273–1296, Dec. 2018, doi: 10.1007/s11165-016-9602-2.

[37] W. R. King and J. He, "A meta-analysis of the technology acceptance model," *Information & Management*, vol. 43, no. 6, pp. 740–755, Sep. 2006, doi: 10.1016/j.im.2006.05.003.

[38] J. Molina-Maturano *et al.*, "Understanding smallholder farmers' intention to adopt agricultural apps: the role of mastery approach and innovation hubs in Mexico," *Agronomy*, vol. 11, no. 2, p. 194, Jan. 2021, doi: 10.3390/agronomy11020194.

[39] S. A. Raza, A. Umer, W. Qazi, and M. Makhdoom, "The effects of attitudinal, normative, and control beliefs on m-learning adoption among the students of higher education in Pakistan," *Journal of Educational Computing Research*, vol. 56, no. 4, pp. 563–588, Jul. 2018, doi: 10.1177/0735633117715941.

[40] T. Teo, "Modelling technology acceptance in education: a study of pre-service teachers," *Computers & Education*, vol. 52, no. 2, pp. 302–312, Feb. 2009, doi: 10.1016/j.compedu.2008.08.006.

[41] T. Teo, "Factors influencing teachers' intention to use technology: model development and test," *Computers & Education*, vol. 57, no. 4, pp. 2432–2440, Dec. 2011, doi: 10.1016/j.compedu.2011.06.008.

[42] J. H. Watson and A. Rockinson-Szapkiw, "Predicting preservice teachers' intention to use technology-enabled learning," *Computers & Education*, vol. 168, p. 104207, Jul. 2021, doi: 10.1016/j.compedu.2021.104207.

[43] A. Masek, A. N. P. Halim, S. Hashim, N. S. Abdullah, and W. H. N. W. Muda, "The role of knowledge, emotion, and intention in influencing students' behaviors during COVID-19 pandemic," *SAGE Open*, vol. 12, no. 2, pp. 1–13, Apr. 2022, doi: 10.1177/21582440221089954.

[44] S. C. Kong, Y. Yang, and C. Hou, "Examining teachers' behavioural intention of using generative artificial intelligence tools for teaching and learning based on the extended technology acceptance model," *Computers & Education: Artificial Intelligence*, vol. 7, p. 100328, Dec. 2024, doi: 10.1016/j.caeai.2024.100328.

[45] B. Cabellos, F. Siddiq, and R. Scherer, "The moderating role of school facilitating conditions and attitudes towards ICT on teachers' ICT use and emphasis on developing students' digital skills," *Computers in Human Behavior*, vol. 150, p. 107994, Jan. 2024, doi: 10.1016/j.chb.2023.107994.

[46] A. Baj-Rogowska, "AutoCAD: examination of factors influencing user adoption," *Engineering Management in Production and Services*, vol. 12, no. 1, pp. 45–56, May 2020, doi: 10.2478/emj-2020-0004.

[47] Y. Zhao, Y. Sun, Q. Zhou, C. Cui, and Y. Liu, "How A/E/C professionals accept BIM technologies in China: a technology acceptance model perspective," *Engineering, Construction and Architectural Management*, vol. 30, no. 10, pp. 4569–4589, Nov. 2023, doi: 10.1108/ECAM-04-2022-0308.

[48] R. Howard, L. Restrepo, and C.-Y. Chang, "Addressing individual perceptions: an application of the unified theory of acceptance and use of technology to building information modelling," *International Journal of Project Management*, vol. 35, no. 2, pp. 107–120, Feb. 2017, doi: 10.1016/j.ijproman.2016.10.012.

[49] L.-Y.-K. Wang, S.-L. Lew, S.-H. Lau, and M.-C. Leow, "Usability factors predicting continuance of intention to use cloud e-learning application," *Heliyon*, vol. 5, no. 6, p. e01788, Jun. 2019, doi: 10.1016/j.heliyon.2019.e01788.

[50] D. Y. Lee and M. R. Lehto, "User acceptance of YouTube for procedural learning: an extension of the technology acceptance model," *Computers & Education*, vol. 61, pp. 193–208, Feb. 2013, doi: 10.1016/j.compedu.2012.10.001.

BIOGRAPHIES OF AUTHORS

Basyirun is an associate professor in Vocational Education in Mechanical Engineering at the Ph.D. Vocational Education Program, Graduate School, Universitas Negeri Semarang, Indonesia. His research focuses on vocational education and training (VET), with particular interests in mechanical engineering education, welding engineering education, technical and vocational teacher development, competency-based training, and curriculum innovation in vocational and technical education. His scholarly work contributes to the advancement of vocational learning and workforce preparation in engineering-related fields. He can be contacted at email: basyirun@mail.unnes.ac.id.

Andri Setiyawan is an assistant professor in Automotive Engineering Education at the Department of Mechanical Engineering, Universitas Negeri Semarang, Indonesia, and is affiliated with Johannes Kepler University Linz, Austria. His research focuses on STEM and vocational education, engineering education, engineering drawing, pre-service teacher development, and the integration of digital technologies, including 3D modeling, 3D printing, and artificial intelligence, in teaching and learning. He can be contacted at email: andryaam@gmail.com; andrisetiyawan@mail.unnes.ac.id.

Soeharto holds a Ph.D. and is a senior researcher at Indonesia's National Research and Innovation Agency (BRIN) and is also affiliated with the Center for Educational Technologies at the Azerbaijan State University of Economics (UNEC). He has contributed to international research on teacher education and instructional technologies, including work on vocational and digital learning environments, and collaborates with researchers in technology-enhanced learning and media studies. His scholarly activities include publishing in peer-reviewed journals and engaging in interdisciplinary projects that explore how technology and media shape educational practice. He can be contacted at email: soeharto@brin.go.id.

Daniel Jarvis teaches courses in the teacher education (B.Ed.) and graduate education (M.Ed./Ph.D.) programs within the Schulich School of Education at Nipissing University in North Bay, Ontario, Canada. His research interests include mathematics education, instructional technology, mathematics of the workplace, curriculum integration, and STEAM education. He can be contacted at email: danj@nipissingu.ca.

Jan Vaněk is an academic at the Department of Technical and Vocational Education at Ostrava University's Faculty of Education, where his work focuses on applied mechanics, modeling of technical systems with didactics, and technical experiments, and he teaches and supervises theses in these areas. He has contributed to numerous publications and conference proceedings on topics ranging from modern trends in surface engineering and the use of geometric solids in technology teaching to STEAM integration. Jan is actively involved in research projects and academic activities that support the preparation of vocational subject teachers and the integration of innovative educational practices within technical and vocational education. He can be contacted at email: jan.vanek@osu.cz.

Zsolt Lavicza has worked on several research projects examining technology and mathematics teaching in classroom environments in Michigan and Cambridge. In addition, Zsolt has greatly contributed to the development of the GeoGebra community and participated in developing research projects on GeoGebra and related technologies worldwide. Currently, Zsolt is a professor in STEM Education Research Methods at Johannes Kepler University's Linz School of Education. At Johannes Kepler University, he works on numerous research projects worldwide related to technology integration into schools, leading the doctoral program in STEM Education, teaching educational research methods worldwide, and coordinating research projects within the International GeoGebra Institute. He can be contacted at email: zsolt.lavicza@jku.at.