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A 3C-TPB Model of Cryptocurrency Education Readiness: Evidence from Romania

Dominic Bucerzan, Mihaela Muntean, Crina Anina Bejan, El Mahdi Mouloua, Mustapha Najmeddine and Camelia Nadia Bran

Dominic Bucerzan
Faculty of Exact Sciences
"Aurel Vlaicu" University of Arad
Campus M,Elena Dragoi, 2, 310330, Arad, Romania
dominic.bucerzan@uav.ro

Mihaela Muntean
Faculty of Economics and Business Administration
West University of Timişoara
Blvd. V. Parvan, nr. 4, 300223, Timişoara, Romania
mihaela.muntean@e-uvt.ro

Crina Anina Bejan*
Faculty of Exact Sciences
"Aurel Vlaicu" University of Arad
Campus M,Elena Dragoi, 2, 310330, Arad, Romania
*Corresponding author: crina.bejan@uav.ro

El Mahdi Mouloua
Meknes Department of Mathematics
Moulay Ismail University ENSAM
Presidency, Marjane 2, BP:298, Meknes, 050000, Morocco
e.mouloua@edu.umi.ac.ma

Mustapha Najmeddine
Meknes Department of Mathematics
Moulay Ismail University ENSAM
Presidency, Marjane 2, BP:298, Meknes, 050000, Morocco
m.najmeddine@umi.ac.ma

Camelia Nadia Bran
School of Education
University College Cork
Leeholme, O'Donovan's Road, Cork, T12 HF72, Ireland
cbran@ucc.ie

Abstract

Cryptocurrency systems integrate computing, communication, and control mechanisms; therefore, they create a need for structured education to support understanding and innovation. Public readiness for cryptocurrency education has been investigated across behavioral, technological, and regulatory dimensions. Previous studies have approached these dimensions in isolation, without a unified framework to explain their combined influence on readiness and behavioral intention. To address this gap, this paper examines the conditions that shape readiness for institutionalized cryptocurrency education and explores their effects on behavioral intention. The Theory of Planned Behavior was integrated with a Computing–Communications–Control structure to establish the proposed research model. Readiness is viewed as the product of computing-related capabilities, communication processes, and regulatory conditions. A survey was conducted with 476 adults in Romania. Based on Partial Least Squares Structural Equation Modeling, the findings reveal that perceived behavioral control is positively influenced by education, financial literacy, and system familiarity. Behavioral intention is positively predicted by perceived behavioral control and regulatory clarity. Within the communication dimension, social media influence positively predicts subjective norms. However, subjective norms show a negative relationship with intention, pointing to a counterintuitive dynamic in how communication conditions operate in this context. This work introduces a system-level framework that connects capability formation, communication dynamics, and control conditions within a unified structure. It provides a foundation for designing cryptocurrency education programs that integrate technical competence, information evaluation, and regulatory awareness.

Keywords: Computing-Communications-Control; Cryptocurrency; Education; Theory of Planned Behavior; PLS-SEM.

1 Introduction

The expansion of digital finance through cryptocurrency raises new demands for computing, communication, and control processes in higher education. Cryptocurrency functions within distributed computing environments, networked communication systems, and regulated financial infrastructures. Although these technologies continue to advance in finance, logistics, and governance, formal educational programs remain limited [21]. This gap between technological diffusion and formalized education raises concerns about technical competence, financial literacy, and regulatory awareness [34, 37]. Existing research has treated cryptocurrency adoption, investment behavior, and technical skills independently. Limited work examines cryptocurrency education readiness as a system that connects capability formation, information flow, and regulatory conditions within a unified behavioral model. Institutionalization of cryptocurrency education is further constrained by public skepticism, market volatility, fraud cases, and regulatory uncertainty [30, 61].

The Theory of Planned Behavior (TPB) provides a framework for analyzing intention formation through attitudes, subjective norms, and perceived behavioral control. In this study, TPB is positioned within a Computing-Communications-Control (3C)structure. The computing dimension captures technical knowledge and understanding of blockchain systems. The communications dimension captures information flow and social influence processes in online environments. The control dimension captures perceived regulatory clarity and institutional conditions. These three dimensions supply the system input that shapes attitude, subjective norms, and perceived behavioral control. Figure 1 presents the integrated 3C-TPB framework.

Romania provides an empirical context for examining the readiness for institutionalized cryptocurrency education within an EU regulatory setting [50, 60]. Cryptocurrency use is present in Romania, while formal educational initiatives remain limited and public warnings have documented risks associated with low literacy and fraud exposure [23, 55]. This context allows for an assessment of how technical competence, information networks, and perceived regulatory conditions relate to intention and engagement with cryptocurrency education.

This study defines and tests a model that integrates a Computing-Communications-Control perspective with the Theory of Planned Behavior. The model measures computing-related constructs (education, financial literacy, familiarity, technology awareness, and attitude), communications-related constructs (social media influence and subjective norms), and control-related constructs (perceived behavioral control and perceived regulatory clarity) as predictors of behavioral intention and self-reported engagement. The model is evaluated using Partial Least Squares Structural Equation Modeling (PLS-SEM) on survey data from 476 Romanian adults.

Compared to existing models such as TPB-only or UTAUT (Unified Theory of Acceptance and Use of Technology)-based approaches, the proposed 3C-TPB framework adds a system-level structuring layer that integrates technical capability formation, communication processes, and regulatory conditions into a unified analytical model. This integration extends traditional behavioral approaches by embedding them within a broader socio-technical system perspective.

Section 2 presents the theoretical background and the integrated 3C-TPB framework. Section 3 describes the research model, hypotheses, and methodology. Section 4 reports the empirical results. Section 5 discusses results implications. Section 6 concludes the study and outlines limitations and directions for future research.

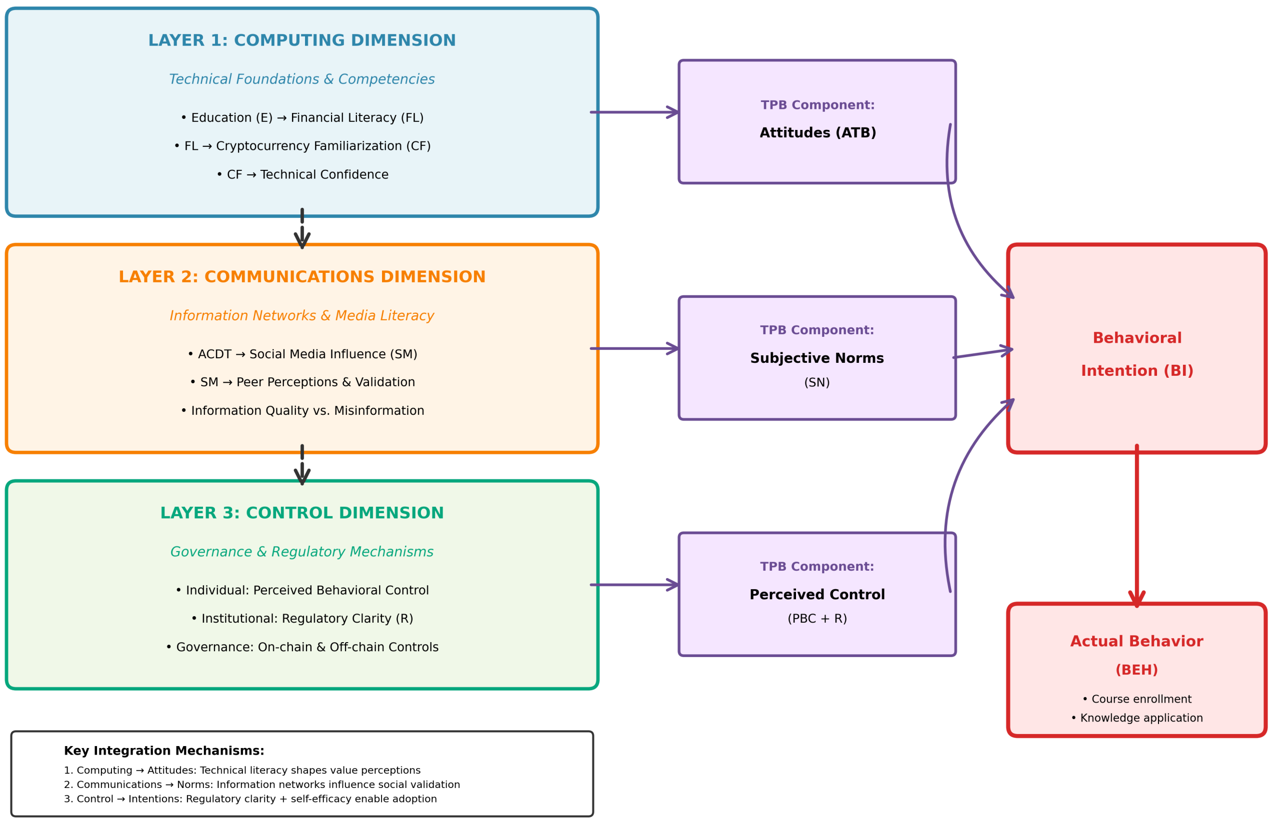

Figure 1: Integrated 3C-TPB Framework for Institutionalized Cryptocurrency Education Adoption

2 Background and Theoretical Framework

To position the model as a 3C system, the Computing–Communications–Control perspective is used as a structuring layer that groups antecedents by system function. The computing subsystem captures capability formation required for understanding blockchain architectures and smart contracts [4, 7, 14, 47]. The communications subsystem captures information diffusion and social influence processes in online networks, including exposure to misinformation [57, 64]. The control subsystem represents perceived constraints and enabling conditions linked to regulatory clarity and compliance expectations [27, 36, 43, 69]. TPB provides the behavioral mechanism linking attitude, subjective norms, and perceived behavioral control to intention and behavior [1, 18]. This separation clarifies which parts of readiness are related to capability formation, information processes, and perceived governance conditions, while keeping the behavioral prediction structure of TPB.

2.1 The 3C Framework in Cryptocurrency Education

The 3C framework conceptualizes readiness for institutionalized cryptocurrency education as an interacting socio-technical system composed of three subsystems: computing capability formation, communication-driven norm construction, and regulatory control conditions. Cryptocurrency ecosystems operate simultaneously as distributed computing infrastructures, information networks, and regulated financial environments. Accordingly, readiness depends on technical competence, information processing capacity, and perceived governance conditions.

Computing Dimension. The computing subsystem represents the technical capability required to understand distributed ledger architectures, consensus mechanisms, and smart contracts [4, 7, 14, 47]. Beyond technical literacy, individual technology readiness traits (optimism, innovativeness, discomfort, and insecurity) have been empirically linked to cryptocurrency adoption in PLS-SEM and deep-learning ANN analyses [9]. In educational contexts, this includes knowledge of system security, transaction validation, and computational risk assessment [16]. Technical competence forms the basis for evaluating cryptocurrency systems and therefore shapes readiness for formalized education in this domain. Comparable PLS-SEM work in Romania finds that program design and business-sector inputs shape technology-related competencies that translate into labor-market readiness [12].

Communications Dimension. The communications subsystem captures how information flows across digital networks shape collective perceptions and normative pressures. Online platforms function as distributed communication systems in which content spreads through user interaction and network effects [64]. These environments also enable the circulation of misinformation and fraudulent schemes [57, 63]. Evidence from teen Reddit communities documents minors' access patterns (often via parents' accounts), short-term profit/entertainment motivations, and frequent harms (scams, key loss), underscoring the risk and information-quality challenges in social platforms [13]. Network structure matters: small-group effects on multilayer social networks can speed up the spread of information and behaviors, altering how normative cues propagate [68]. Beyond misinformation, herding and heuristic biases have been shown to shape cryptocurrency decisions and moderate the positive role of knowledge [11]. Exposure to influencer endorsement, peer interaction, and shared content affects attitudes and behavioral intentions in cryptocurrency contexts [10, 32, 58]. Mass influence mechanisms in digital environments have been analyzed in classical and contemporary literature. Information processes therefore contribute to the formation of subjective norms related to cryptocurrency education. Complementing regulatory clarity, cross-country panel results indicate that macro conditions (inflation, interest/exchange rates) and network readiness co-move with cryptocurrency adoption [28].

Control Dimension. The control subsystem represents regulatory and governance mechanisms that reduce perceived uncertainty and define operational boundaries. From a systems perspective, regulation functions as a feedback mechanism that establishes constraints and compliance standards [69]. Regulatory clarity is associated with reduced uncertainty and greater institutional adoption [36]. Within the European Union framework, the Markets in Crypto-Assets Regulation (MiCA) defines harmonized regulatory conditions [43]. AML (Anti-Money Laundering) and CTF (Counter-Terrorism Financing) requirements impose compliance obligations on cryptocurrency service providers [27]. Governance mechanisms such as decentralized autonomous organizations illustrate on-chain control structures. Institutional governance and trust influence blockchain adoption outcomes [2, 49]. Educational programs must therefore address regulatory, governance, and ethical dimensions [51, 60].

Integration of the 3C Dimensions. The 3C framework represents readiness as the interaction of computing capability, communication processes, and perceived regulatory conditions. Technical competence enables system understanding, communication networks shape normative pressures, and governance conditions define perceived constraints. These subsystems jointly influence intention and engagement with institutionalized cryptocurrency education.

2.2 Theory of Planned Behavior in Technology Adoption

Within this study, TPB operates as the behavioral implementation layer of the 3C system. The Theory of Planned Behavior explains behavioral intention through attitudes, subjective norms, and perceived behavioral control [1, 18]. Attitudes reflect evaluation of outcomes, subjective norms reflect perceived social pressure, and perceived behavioral control reflects perceived capability and resource availability. These constructs jointly determine behavioral intention, which predicts behavior.

Applications of TPB in technology contexts include analyses of artificial intelligence adoption [65] and cryptocurrency investment intention [8, 38, 45]. Regulatory frameworks influence perceived behavioral control by reducing perceived risk [62]. Digital financial literacy contributes to individuals' capacity to evaluate cryptocurrency-related activities [29, 32, 33, 37, 54, 59]. Institutional leadership and curriculum decisions influence subjective norms in higher education [5, 30, 35, 48, 61]. Structured education programs are associated with competence development in emerging domains [52].

2.3 Literature Gap and Research Positioning

Existing research applying TPB to cryptocurrency has focused mainly on individual investment intentions from psychological perspectives [32, 38]. While these studies explain how attitudes and social influence shape adoption, they do not address cryptocurrency education within its broader technical and institutional context.

Research on cryptocurrency education has examined computing competencies [4, 7], communication dynamics [57, 64], regulatory requirements [36, 69], and behavioral-finance influences on crypto decisions [11], separately. Related work also models technology readiness as a driver of cryptocurrency adoption using hybrid PLS-SEM-ANN approaches [9], yet these factors are rarely integrated with governance conditions in a single structural model.Universities have introduced programs that integrate technical and regulatory content [26, 44, 46]; however, few studies examine how the interaction between these dimensions influences educational adoption. Related Romanian evidence links education–business collaboration to technology-skills development via PLS-SEM; however, these models do not integrate communication and governance layers like the proposed 3C-TPB structure does [12]. At the macro level, recent panel evidence integrates technological, monetary, and governance factors in explaining adoption across 37 countries, but such drivers are rarely linked to education-readiness within a unified behavioral framework [28]. Studies on blockchain governance highlight institutional mechanisms [2, 49], and research on digital literacy examines information network effects [29, 58, 59], but these strands are generally treated independently.

Prior research has examined these dimensions separately, including technical competencies [4, 7], communication dynamics and misinformation [57, 64], and regulatory and governance mechanisms [36, 49, 69]. Applications of TPB in cryptocurrency contexts have focused primarily on individual adoption or investment intentions [32, 38, 45], without integrating these technical, informational, and regulatory dimensions within a unified structural model of educational readiness.

Building on Clark's institutional perspective [17], which links technical capacity, social legitimacy, and regulatory acceptance, this study uses a 3C layered structure together with TPB. The model links computing capability formation, communication-based norm construction, and perceived regulatory conditions to behavioral intention and engagement with institutionalized cryptocurrency education. In this way, TPB explains how intention is formed, while the 3C framework explains how the relevant antecedent conditions are organized. This framing is different from TPB-only models, which focus on behavioral predictors without structuring the broader socio-technical environment, from UTAUT-type models, which emphasize performance and social influence in technology use, and from technology readiness models, which focus on personal predispositions toward technology. The Romanian context [23, 24, 55] provides an empirical setting to test this integrated structure.

3 Research Model and Methodology

This study applies PLS-SEM to test the proposed 3C-TPB framework in Romanian context. The model includes thirteen hypotheses ***(H1-H13)*** linking the computing, communications, and control dimensions to the components of the TPB. Data were collected through a structured survey administered to Romanian adults between October 2023 and September 2024. Statistical analysis was conducted using SmartPLS 4 [53], and bootstrapping procedures were applied to evaluate the significance of direct and indirect relationships among constructs.

3.1 Theoretical Model and Hypothesis Development

The proposed structural model integrates the 3C framework with the TPB to explain readiness for institutionalized cryptocurrency education. The model specifies directional relationships among education (E), financial literacy (FL), cryptocurrency familiarization (CF), awareness of cryptocurrency disruptive technology (ACDT), social media influence (SM), subjective norms (SN), perceived behavioral control (PBC), attitude toward behavior (ATB), legislative regulations (R), behavioral intention (BI), and behavior (BEH).

Prior research indicates that education enhances technological awareness, financial competence, and attitudes toward emerging technologies [6, 15, 39, 52]. Within the computing dimension, education is modeled as a primary antecedent: ***H1:*** *Education positively influences awareness of cryptocurrency disruptive technology*; ***H2:*** *Education positively influences financial literacy*; ***H3:*** *Education positively influences attitude toward institutionalized cryptocurrency education.*

Financial literacy supports technological familiarization, and technical competence increases perceived behavioral control [22, 33, 38]. Financial literacy was measured as perceived financial competence rather than objective knowledge. Within the TPB framework, perceived capability is relevant, as behavioral intentions are shaped by subjective evaluations of one's own competence. In this study, higher educational attainment was expected to be associated with stronger perceived financial literacy, reflecting differences in exposure to economic and analytical training. Education may enhance critical evaluation of digital information sources. ***H4:*** *Financial literacy positively influences cryptocurrency familiarization*; ***H5:*** *Cryptocurrency familiarization positively influences perceived behavioral control*; ***H6:*** *Awareness of cryptocurrency disruptive technology positively influences perceived behavioral control.*

Individuals with greater technological awareness may engage differently with digital information sources, influencing the extent to which social media shapes their perceptions [5]. Within the communications dimension, technological awareness is associated with engagement in digital information networks [5]. Social media exposure shapes subjective norms, which influence behavioral intention. [5, 48]: ***H7:*** *Awareness of cryptocurrency disruptive technology influences social media influence*; ***H8:*** *Social media influence positively affects subjective norms*; ***H9:*** *Subjective norms influence behavioral intention to engage in cryptocurrency education.*

The control dimension includes perceived behavioral control and regulatory clarity. Consistent with TPB [1], both perceived behavioral control and attitudes determine behavioral intention. Regulatory frameworks reduce uncertainty and strengthen adoption intentions [1, 62]: ***H10:*** *Perceived behavioral control positively influences behavioral intention*; ***H11:*** *Attitude toward behavior positively influences behavioral intention*; ***H12:*** *Legislative regulations positively influence behavioral intention.*

Finally, behavioral intention predicts actual engagement behavior [1, 62]: ***H13:*** *Behavioral intention positively influences behavior.*

The resulting structural model operationalizes the computing, communications, and control dimensions as interacting pathways converging on behavioral intention and realized engagement. Table 1 summarizes the proposed relationships.

Table 1: Hypotheses Categorized within the Integrated 3C-TPB Framework

Hyp.	**3C Dimension**	**TPB Component**	**Construct Relationship**
H1	Computing	Attitudes	E $\rightarrow$ ACDT
H2	Computing	Attitudes	E $\rightarrow$ FL
H3	Computing	Attitudes	E $\rightarrow$ ATB
H4	Computing	Perceived Control	FL $\rightarrow$ CF
H5	Computing	Perceived Control	CF $\rightarrow$ PBC
H6	Computing	Perceived Control	ACDT $\rightarrow$ PBC
H7	Communications	Subjective Norms	ACDT $\rightarrow$ SM
H8	Communications	Subjective Norms	SM $\rightarrow$ SN
H9	Communications	Behavioral Intention	SN $\rightarrow$ BI
H10	Control	Behavioral Intention	PBC $\rightarrow$ BI
H11	Computing	Behavioral Intention	ATB $\rightarrow$ BI
H12	Control	Behavioral Intention	R $\rightarrow$ BI
H13	Integration	Actual Behavior	BI $\rightarrow$ BEH

3.2 Research Design and Data Collection

3.2.1 Survey Development and Validation

A structured questionnaire was developed to measure constructs using multiple items, drawing from existing literature on financial literacy, cryptocurrency education, and the TPB framework. The questionnaire consisted of two sections: demographic information (gender, education, residence, age group) and construct measurement items using a 5-point Likert scale (1 = Strongly Disagree, ..., 5 = Strongly Agree). Education was modeled as a binary exogenous single-indicator construct (0 = High School or less; 1 = Postgraduate). In the Romanian context, educational attainment represents a meaningful distinction in exposure to financial and economic knowledge. As a categorical predictor, path coefficients associated with education reflect mean differences between educational groups rather than standardized effects. It was included in the structural model as a single-indicator predictor. Because education was modeled as a binary exogenous variable, path coefficients associated with this construct represent unstandardized mean differences between educational groups rather than standardized effects. Therefore, their magnitude is not directly comparable to latent-to-latent standardized path coefficients. All other constructs were operationalized as reflective latent variables measured by multiple indicators within the 3C-TPB framework. Reflective specification was chosen because the indicators represent manifestations of the underlying latent constructs rather than distinct causal components.

Pilot testing was conducted with 30 individuals representative of the target population. Feedback from this phase refined the clarity and relevance of questions. Professionals in education, finance, and cryptocurrency reviewed the content for relevance and alignment with study objectives. Content validity was strengthened by ensuring items reflected theoretical constructs from the TPB framework and existing research. Table 2 presents the construct definitions organized by 3C dimensions.

Table 2: Construct Definitions and Measurement Items within the 3C-TPB Framework

3C	TPB	Construct	Definition	Survey Items
Computing	Attitudes	E	Educational attainment	High School or less (Post)Graduate
Computing	Attitudes	FL	Financial competence	FL1: I understand basic financial concepts; FL2: I can evaluate financial risks; FL3: I feel confident managing finances; FL4: I am knowledgeable about investment options; FL5: I can make informed financial decisions
Computing	Perceived Control	CF	Cryptocurrency familiarity	CF1: I am familiar with how cryptocurrencies work; CF2: I understand blockchain technology; CF3: I know different cryptocurrency types; CF4: I know how to securely store cryptocurrencies; CF5: I am aware of benefits and risks
Computing	Attitudes	ACDT	Awareness of disruptive potential	ACDT1: Cryptocurrency can disrupt traditional financial systems; ACDT2: It can transform business operations; ACDT3: I understand technological innovations; ACDT4: It is changing transaction systems; ACDT5: It represents economic shift
Computing	Attitudes	ATB	Attitude toward education	ATB1: Learning about cryptocurrency is beneficial; ATB2: I find adopting cryptocurrency education exciting
Commun.	Subj. Norms	SM	Social media influence	SM1: Social media is my primary cryptocurrency information source; SM2: Social media influences my perception; SM3: I engage with cryptocurrency content; SM4: I trust influencer opinions; SM5: Social media shapes my awareness
Commun.	Subj. Norms	SN	Subjective norms	SN1: People I value think I should learn; SN2: Friends and family encourage me to adopt education
Control	Perceived Control	PBC	Behavioral control	PBC1: I feel confident learning about cryptocurrency; PBC2: I have necessary resources and tools
Control	–	R	Regulations	R1: Government regulations make cryptocurrency safer; R2: Clear regulations encourage adoption
Integration	Behav. Intent.	BI	Behavioral intention	BI1: I intend to engage in cryptocurrency education; BI2: I plan to apply knowledge in practice
Integration	Actual Behavior	BEH	Actual behavior	BEH1: I have participated in cryptocurrency education; BEH2: I have applied knowledge in practice

3.2.2 Data Collection Process

Responses were collected over eleven months, from October 2023 to September 2024, through an online survey distributed to participants residing in Romania. Data collection spanned multiple months; therefore, responses reflect aggregated perceptions rather than reactions to a single short-term market event. Inclusion criteria required participants to be at least 18 years old, currently residing in Romania, and capable of providing informed consent. A total of 1045 responses were initially collected. Validation procedures screened for incomplete responses, inconsistent responses, and duplicate entries. After applying these criteria, 476 valid responses were retained for analysis. This dataset, representative of the target population, provided foundation for testing hypotheses and evaluating Romanian public acceptance and readiness for institutionalized cryptocurrency education.

Table 3 presents respondent characteristics.

Table 3: Demographic Characteristics of Respondents (n = 476)

Variable	Category	Frequency	Percentage (%)
Gender	Female	240	50.43
	Male	236	49.57
Education	(Post)Graduate	348	73.11
	High School or less	128	26.89
Residence	Urban	239	50.22
	Rural	237	49.78
Age Group	18–45	384	80.67
	Over 45	92	19.33

3.3 Data Analysis Methodology

PLS-SEM was employed to analyze the relationships among latent variables and assess the hypothesized model. PLS-SEM is suited for studies involving latent variables, complex constructs, and small-to-medium sample sizes. This method enables simultaneous evaluation of measurement and structural models, making it appropriate for exploring emerging fields like cryptocurrency education, where theoretical foundations continue to develop [67]. PLS-SEM handles non-normal data distributions and facilitates analysis of path coefficients and indirect effects [3]. Bootstrapping was integrated into the analysis to validate statistical significance of path coefficients, providing confidence intervals and t-statistics for both direct and indirect effects. The analysis was conducted using SmartPLS 4 [53]. Recent studies on education-technology competencies in Romania likewise apply PLS-SEM to model competency formation and downstream outcomes [12]. Comparable PLS-SEM analyses of cryptocurrency intention in student samples also use SmartPLS [10]. Related Romanian perception-based studies have also used multivariate exploratory techniques, such as hierarchical clustering, to identify respondent profiles and patterns in survey data [20]. The conceptual model (Figure 2) depicts hypothesized relationships among latent variables. To assess potential common method bias, full collinearity variance inflation factors were examined. Values were below the recommended threshold of 3.3, suggesting that common method variance is unlikely to bias the structural estimates.

The structural model was assessed for significance and explanatory power, with R^2 values indicating moderate-to-strong predictive relevance for key dependent variables. Model fit was evaluated using the Standardized Root Mean Square Residual (SRMR). Reliability and validity were confirmed with Composite Reliability (CR) and Average Variance Extracted (AVE) values exceeding recommended thresholds for all constructs. The analysis included education and legislative regulations as factors influencing public acceptance and readiness for institutionalized cryptocurrency education in Romania.

4 Results

This section presents the empirical validation of the three interdependent subsystems proposed by the 3C framework. The study employed PLS-SEM with bootstrapping analysis to validate constructs and test hypotheses. The tests confirmed measurement model reliability and structural relationships among constructs within the 3C-TPB framework.

4.1 Sample Characteristics

Data were collected from 476 Romanian respondents with balanced gender distribution (50.43% female, 49.57% male). The sample exhibited high educational attainment (73.11% (post)graduate), equal urban-rural representation (50.22% urban, 49.78% rural), and predominance of younger participants (80.67% aged 18-45). Urban residents showed slightly higher support for cryptocurrency education (65.88%) compared to rural residents (62.86%), while older respondents (67.80%) demonstrated greater support than younger ones (63.29%).

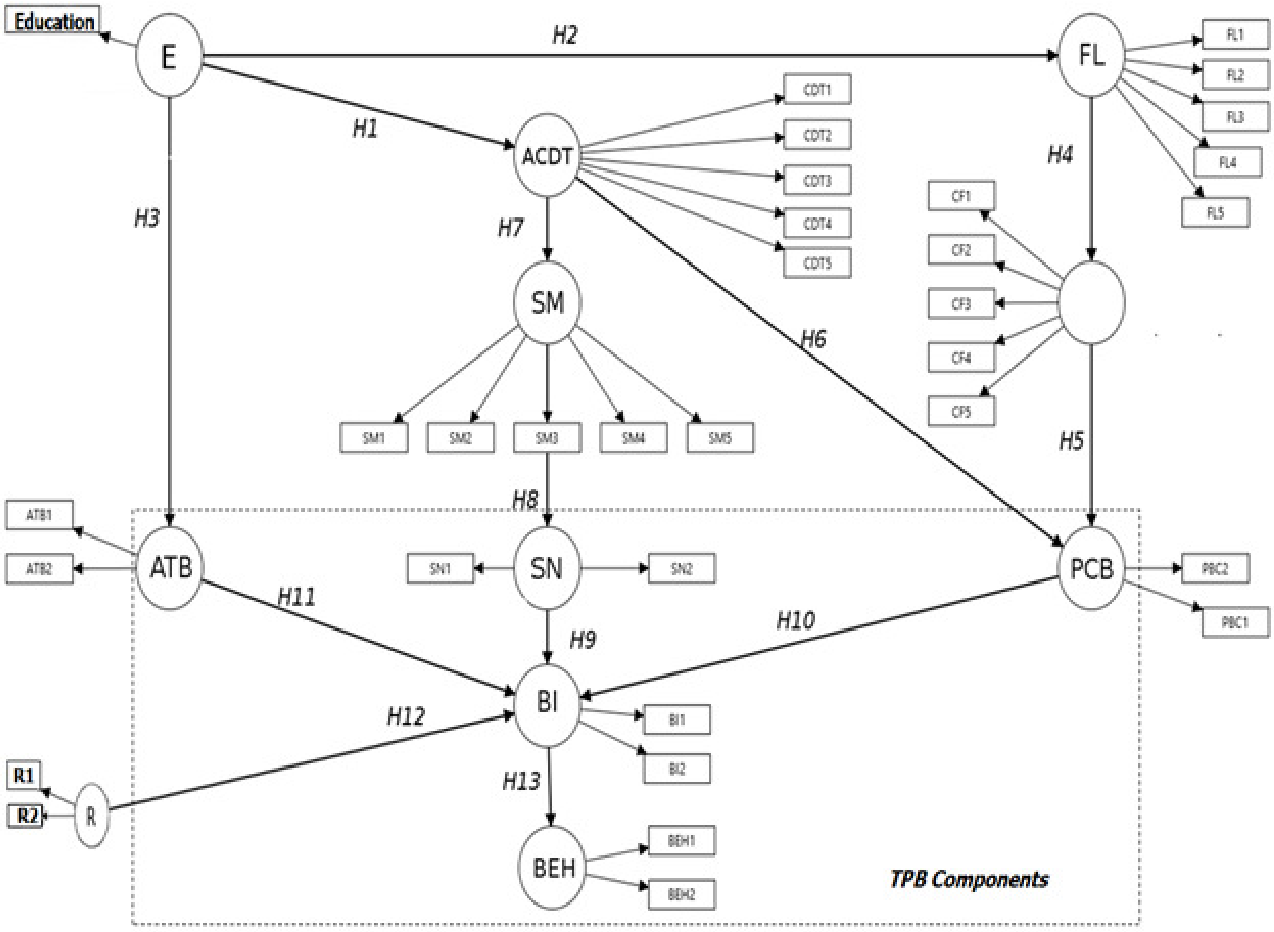

Figure 2: Conceptual model integrating the Computing-Communications-Control (3C) dimensions within the Theory of Planned Behavior. Hypothesized relationships among constructs are shown.

The measurement model shows internal consistency and convergent validity. Composite reliability values ranged from 0.746 to 0.843, exceeding the recommended threshold of 0.70. Average Variance Extracted (AVE) values were above 0.50 for all constructs, confirming convergent validity. Indicator loadings were generally above 0.70, supporting indicator reliability. Variance Inflation Factors (VIF) were below 1.5, indicating absence of multicollinearity.

Table 4 presents R^2 values and table 5 presents hypothesis testing results. Education explains a large proportion of variance in perceived financial literacy ($R^2 = 0.767$), indicating a strong association between tertiary education and self-assessed financial competence in the Romanian sample: FL (76.7%), ACDT (64.8%), ATB (52.3%), CF (42.6%), SM (40.9%), BI (37.6%), SN (32.3%), PBC (26.6%), and BEH (22.2%).

Table 4: R^2 Values

Construct	R^2
FL	0.767
ACDT	0.648
ATB	0.523
CF	0.426
SM	0.409
BI	0.376
SN	0.323
PBC	0.266
BEH	0.222

4.2 Structural Model Assessment

Bootstrapping with 5,000 resamples was conducted to evaluate the significance of structural relationships. The structural model demonstrated moderate explanatory power, explaining 37.6% of variance in behavioral intention ($R^2 = 0.376$) and 22.2% in actual behavior ($R^2 = 0.222$), consistent with Theory of Planned Behavior applications in emerging technology contexts.

Within the computing dimension, financial literacy significantly predicted cryptocurrency familiarization ($\beta = 0.653$, $t = 27.34$, $p < 0.001$). Cryptocurrency familiarization positively influenced perceived behavioral control ($\beta = 0.299$, $t = 6.05$, $p < 0.001$), while awareness of cryptocurrency disruptive technology also contributed positively to perceived behavioral control ($\beta = 0.271$, $t = 5.55$, $p < 0.001$).

Education, modeled as a binary exogenous predictor (0 = High School or less; 1 = (Post)Graduate), significantly increased financial literacy ($\beta = 1.977$, $t = 49.50$, $p < 0.001$), awareness of disruptive technology ($\beta = 1.817$, $t = 47.28$, $p < 0.001$), and attitude toward cryptocurrency education ($\beta = 1.633$, $t = 33.55$, $p < 0.001$), indicating substantial mean differences between educational groups.

Within the communications dimension, awareness of disruptive technology negatively predicted social media influence ($\beta = -0.639$, $t = 25.09$, $p < 0.001$), suggesting that greater technological literacy reduces reliance on social media sources. Social media influence positively predicted subjective norms ($\beta = 0.568$, $t = 19.44$, $p < 0.001$). However, subjective norms negatively predicted behavioral intention ($\beta = -0.177$, $t = 4.37$, $p < 0.001$), contrary to classical TPB expectations.

Within the control dimension, perceived behavioral control ($\beta = 0.127$, $t = 3.25$, $p = 0.001$), attitude toward behavior ($\beta = 0.257$, $t = 5.49$, $p < 0.001$), and regulatory clarity ($\beta = 0.239$, $t = 5.51$, $p < 0.001$) significantly predicted behavioral intention. Behavioral intention strongly predicted actual behavior ($\beta = 0.471$, $t = 14.25$, $p < 0.001$).

Table 5: Hypothesis Testing Results

Hypothesis	**Coeff.**	**t-value**	**Result**
H1: E → ACDT	1.977	49.498	Supported
H2: E → FL	1.817	47.275	Supported
H3: E → ATB	1.633	33.548	Supported
H4: FL → CF	0.653	27.337	Supported
H5: CF → PBC	0.299	6.053	Supported
H6: ACDT → PBC	0.271	5.551	Supported
H7: ACDT → SM	-0.639	25.092	Significant (opposite direction)
H8: SM → SN	0.568	19.438	Supported
H9: SN → BI	-0.177	4.372	Significant (opposite direction)
H10: PBC → BI	0.127	3.254	Supported
H11: ATB → BI	0.257	5.493	Supported
H12: R → BI	0.239	5.513	Supported
H13: BI → BEH	0.471	14.254	Supported

All variance inflation factors were below recommended thresholds, reducing the likelihood that the observed sign directions are driven by multicollinearity effects.

5 Discussion

The findings support the integrated 3C-TPB framework in Romania and point to three mechanisms shaping readiness: technical competence (computing), information-network dynamics (communications), and regulatory confidence (control). Computing and control align with TPB, but communications are more complex: subjective norms are negatively related to behavioral intention. This indicates that intention is driven more by attitude and perceived behavioral control than by social pressure, suggesting TPB component weights may vary by technological and cultural context.

5.1 Computing Dimension: Technical Literacy Pathways

The structural relationships indicate that education is associated with higher financial literacy, technological awareness, and attitude toward cryptocurrency education. Financial literacy is associated with familiarity, and familiarity contributes to perceived behavioral control. These pathways suggest that readiness for institutionalized cryptocurrency education is linked to the development of perceived technical and financial competence. Educational programs that address system understanding, risk evaluation, and technological familiarity may therefore influence perceived capability and intention. This emphasis on financial literacy is consistent with recent evidence showing that cryptocurrency transactors exhibit lower financial literacy than investors and may therefore be more vulnerable absent consumer protections [33].

5.2 Communications Dimension: The Role of Subjective Norms

Subjective norms negatively predict behavioral intention, opposite to the positive norm-intention relationship typically reported in TPB. This may reflect skepticism and trust conditions that lead individuals to discount speculative social signals. Consistent with this, herding/heuristic biases can drive cryptocurrency decisions and weaken the role of knowledge, suggesting that some social-media cues operate as noise rather than guidance [11]. Evidence from student samples shows that social platforms are often the primary information source shaping awareness and investment interest, despite limited underlying knowledge [58]. By contrast, student-focused evidence using UTAUT finds that social influence positively predicts intention, and that financial literacy moderates several paths-including the social influence-intention link [10].

One explanation draws on the moderating role of perceived behavioral control (PBC) within TPB. Prior research show that PBC can moderate the effects of attitude and subjective norms on intention: when PBC is high, the influence of attitude on intention tends to increase, while the influence of subjective norms tends to weaken and may even reverse [66]. This pattern has been reported across behaviors like voting, household waste management, and energy use [25]. In the present study, PBC is shaped by education, financial literacy, and system familiarity. These conditions may enable individuals with higher capability to evaluate normative signals more independently and assign them reduced weight when forming intentions. This pattern may also reflect structural features of online networks: in environments with pronounced small-group clustering, diffusion can be amplified in ways that do not translate into stronger intention, depending on group composition and credibility [68].

A second explanation concerns the information environment in which subjective norms develop. Within the 3C framework, normative influence is situated in the communications dimension, represented here by social media channels. Social media plays a role in cryptocurrency discourse, but it is also associated with speculative content, uneven information quality, and herd-driven cues. Existing work suggests that subjective norms tend to have stronger influence in early stages of adoption, before individuals form their own attitudes or gain direct experience [19]. As education and familiarity increase, reliance on social media–based normative signals may decline. Individuals with higher PBC may perceive these cues as unreliable, more noise than guidance. This may explain the negative subjective norms–intention relationship, as users discount social-media norms once they can evaluate them critically.

Social endorsement may not act as a positive cue in contexts marked by volatility, fraud risk, and weak institutional protection - peer recommendations can trigger caution when credibility is uncertain. Cultural factors further shape this relationship: cryptocurrency behavior varies across countries, and in Romania, public fraud warnings and limited formal education may reinforce skepticism over intention. The stronger effect of regulatory clarity suggests institutional assurance matters more than peer influence. Since trust, legitimacy, and cultural orientation were not directly measured, future research should examine these factors explicitly.

Research has also documented inconsistent relationships between subjective norms and intention across TPB studies, with several reports of non-significant or context-dependent effects in technology - related settings [41]. The present results add to this discussion by situating the relationship within the specific context of cryptocurrency education, where normative influence is shaped by communication channels that often present credibility challenges. Future studies may benefit from distinguishing between injunctive and descriptive norms and examining whether the negative association is specific to norms formed through social media or whether it extends to other referent groups, such as family, institutions, or professional communities, which may exert influence through different mechanisms.

The communication dimension requires closer interpretation. In the present model, social media influence is treated as a general indicator of communication exposure, but the information environment is likely more differentiated. Information about cryptocurrency education may come from personal contacts, influencers, online communities, news coverage, or institutional sources such as universities and public guidance channels. These sources do not operate in the same way. Platform structure, source credibility, and information quality may shape whether communication functions as support, persuasion, uncertainty, or noise. The negative relationship between subjective norms and behavioral intention may reflect not only social influence, but also differences in the quality and legitimacy of the information conveying it. The model captures this pathway at a general level. Future research can refine it by distinguishing between platform types, source categories, and information quality.

5.3 Control Dimension: Regulatory Clarity and Intention

Regulatory clarity shows a direct and positive relationship with behavioral intention, which aligns with the role of the control dimension as a governance-level condition that influences readiness. Prior research identifies regulatory uncertainty as a structural constraint in the cryptocurrency domain. The present findings extend this work by indicating that regulatory clarity also shapes intention formation at the individual level, not only at institutional or market levels. In the European setting, where the Markets in Crypto-Assets Regulation is emerging as a central governance framework, the accessibility of regulatory information-how clearly it is communicated and how widely it is disseminated-may influence readiness to the same degree as the content of the regulation itself [31]. Cross-country evidence shows that macro-financial and institutional conditions shape adoption [28]. Firm-level COVID-19 evidence suggests shocks reshape technology responses and resilience, relevant for readiness under uncertainty [56]. Related work highlights the difficulty of protecting minors in crypto contexts, where access may circumvent age restrictions and exposure to harm is documented [13].

5.4 Integrated 3C Framework

The 3C-TPB model reveals three integration mechanisms. First, computing literacy cascades from education through financial competence to behavioral confidence (Computing → Attitudes/PBC). Second, information network effects shape social validation despite misinformation challenges (Communications → Subjective Norms). Third, regulatory clarity is associated with behavioral intention (Control → Behavioral Intention). These dimensions converge in behavioral intention ($R^2 = 0.376$), which predicts actual engagement ($R^2 = 0.222$) [31, 40]. These patterns are consistent with cross-country findings that link network readiness (Computing) and macro-financial/governance conditions (Control) to observed adoption [28]. The model structure indicates that 3C dimensions are jointly associated with behavioral intention. Curriculum initiatives may therefore align technical literacy, information evaluation skills, and regulatory awareness within a coordinated structure.

The value of the 3C framework lies in its role as a structuring layer rather than a substitute for behavioral theory. TPB remains the mechanism explaining intention and behavior through attitude, subjective norms, and perceived behavioral control. The 3C layer adds a different level of analysis by organizing antecedent conditions into computing, communications, and control functions. This allows cryptocurrency education readiness to be examined as a socio-technical and regulatory configuration, rather than only as an individual adoption decision. Compared with TPB-only models, the present framework explains where the antecedents originate. Compared with UTAUT-type approaches, it prioritizes regulatory conditions and information quality in communication channels. Compared with technology readiness approaches, it considers individual tendencies along with governance and communication processes. In this sense, the contribution of the model is the integration of behavioral explanation with system-level categorization of readiness conditions.

5.5 Implications for Curriculum Design

The structure of the model identifies several directions for curriculum design and policy development. For curriculum design, the pattern in which education supports financial literacy, which then supports system familiarity and perceived behavioral control, suggests that program content should follow a sequential structure. Technical topics, financial concepts, and system-level functions are not independent modules; they build on one another. Programs should also emphasize information evaluation and media literacy to mitigate the impact of misinformation. A curriculum that establishes financial fundamentals before introducing system-level content, and that integrates regulatory material throughout rather than isolating it as a separate unit, is more consistent with the capability-formation pathway identified in the model. Evidence from Romania using PLS-SEM on educator surveys shows that collaboration between the educational system and the business sector shapes AI-related competencies that, in turn, align with labor-market demands-reinforcing the call to design programs that integrate technical content with market-relevant skills [12].

In the Romanian context, secondary education could build on existing financial education frameworks [42], while tertiary institutions could develop integrated programs that combine technical, financial, and regulatory components within a unified structure, supported by stronger teacher preparation and a gradual progression from financial, digital, and civic literacy. International reference points, including programs at MIT and the University of Nicosia [44, 46], illustrate how multi-layered cryptocurrency education can be organized.

For digital literacy programs, the negative relationship between subjective norms and intention indicates that information evaluation should be treated as an independent competency. Evidence from a moderated-mediation study shows that while cryptocurrency knowledge increases engagement, behavioral biases can dampen that effect-reinforcing the need to pair technical/financial content with explicit de-biasing and source-evaluation training [11]. Findings among college students-high awareness, reliance on social media, and concerns about volatility and regulation-underscore the need to embed source evaluation and risk literacy in early curricula [58].Technical or financial content alone may not ensure readiness when social-media channels generate unreliable normative cues. Source evaluation, critical financial-information analysis, and media literacy address the communications dimension. While this study focuses on adults, youth evidence shows distinctive harms from social-media crypto participation, supporting age-appropriate modules on scams and key management [13].

The framework has implications for educational policy beyond individual course design. Universities can use the 3C structure to organize cryptocurrency education across computing (blockchain systems, wallets, smart contracts, risk), communications (source evaluation, platform-specific information quality, interpretation of social influence), and control (regulation, compliance, consumer protection, governance). At the pre-university level, financial and digital literacy can prepare students to assess cryptocurrency-related claims before more technical content. At the policy level, initiatives should move beyond awareness-raising to strengthening information-evaluation skills and regulatory understanding. This supports structured curriculum planning, public guidance, and program development.

6 Conclusions

Research on cryptocurrency education readiness is developing and the factors that influence institutional adoption have not been examined in a unified manner. This study analyzes how capability formation, information flow, and regulatory conditions relate to intention and behavior. A 3C-TPB framework was developed and tested using PLS-SEM on data from 476 Romanian adults. The findings confirm that education underlies financial literacy, technology awareness, and attitude formation. These elements converge into readiness through perceived behavioral control and regulatory clarity.

This study contributes to theory by proposing and validating a framework that integrates the TPB with a Computing-Communications-Control structure. This study relies on cross-sectional and self-reported data, which may introduce response bias and limit causal inference. Future research should employ longitudinal and multi-country designs. This integration places readiness within a system-level representation that connects competence development, information networks, and governance perception. Perceived behavioral control and regulatory clarity emerge as the core pathways through which readiness is formed. Subjective norms show a negative association with intention. This pattern points to individual evaluation and perceived capability as the mechanisms through which intention develops, rather than social influence.

The framework also has implications for curriculum design, policy planning, and digital literacy programs. The 3C-TPB structure can inform the design of education systems that align technical content, information evaluation, and regulatory awareness within a single program architecture.

Several limitations should be noted. First, the cross-sectional design allows analysis of associations but not causal relationships or changes in readiness over time. Second, the model relies on self-reported measures, which may be influenced by perception, social desirability, or response style. Third, educational level was treated as a binary variable to capture broad differences in formal education, but this does not reflect variation in educational pathways, fields of study, or level-specific effects relevant to cryptocurrency education readiness. Fourth, the data were collected only in Romania. While this context enables analysis within a defined regulatory and social setting, the findings cannot be directly generalized to countries with different institutional conditions, levels of digital financial literacy, or patterns of trust in emerging financial technologies. Future research can address these limitations through longitudinal designs, cross-country comparisons, and more detailed measures of educational background and information environments.

Future research can extend this work through longitudinal designs, multi-group comparisons, and cross-country models. Examining how regulatory changes influence readiness over time remains a direction the current design was not positioned to address. Future models could test financial literacy as a moderator of communication and control pathways, following evidence in student contexts where financial literacy conditions the effect of social influence and other UTAUT factors on intention [10].

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