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Chapter 9: Digital Citizenship Education and Responsible Technology Use among Adolescents

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Abstract— Digital participation has become inseparable from adolescent learning, communication, identity formation, entertainment, and access to information. This study examines digital citizenship education as a multidimensional educational mechanism for promoting responsible technology use rather than treating digital competence as technical proficiency alone. A central research gap is identified in the weak empirical connection between adolescents' knowledge of digital citizenship principles and their context-dependent behavioral decisions involving privacy, misinformation, cyber-incivility, generative artificial intelligence, and digital wellbeing. The study therefore conceptualizes a digital citizenship knowledge-behavior calibration gap, representing the discrepancy between knowing appropriate online practices and selecting responsible actions in realistic digital situations. The proposed framework integrates digital ethics, critical information evaluation, AI literacy, privacy management, online interpersonal responsibility, and self-regulation of technology use. It further introduces a machine-learning perspective in which patterns of responsible and potentially risky digital decision-making can be analyzed without reducing adolescent behavior to simple screen-time measures.

Keywords— Digital Citizenship Education, Responsible Technology Use, Adolescents, Artificial Intelligence Literacy, Digital Wellbeing, Online Ethics

Introduction

Digital technologies now constitute an important part of the social and educational environments in which adolescents develop. Smartphones, social networking platforms, learning-management systems, video-sharing services, gaming environments, algorithmic recommender systems, and increasingly generative artificial intelligence applications influence how young people acquire information, maintain relationships, complete academic work, and express identity. Consequently, the educational question is no longer whether adolescents should interact with digital technologies, but whether they possess the competencies and dispositions required to interact with them critically, safely, ethically, and purposefully.

The concept of **digital citizenship** provides a useful framework for addressing this challenge. Contemporary interpretations extend beyond basic Internet safety to include information and data literacy, communication, content creation, privacy, security, participation, critical thinking, ethical conduct, and wellbeing. The European Commission's DigComp 2.2 framework, for example, incorporates more than 250 examples

of digital knowledge, skills, and attitudes and explicitly expands digital competence to emerging artificial-intelligence environments. Such frameworks indicate an important conceptual transition: competent participation in digital society requires not merely operating technology but understanding how technologically mediated decisions affect the individual and others.

This transition is particularly consequential during adolescence. Young people routinely encounter decisions involving whether to disclose personal information, repost unverified material, intervene in cyberbullying, accept algorithmically recommended content, communicate anonymously, use AI-generated material in schoolwork, respond to emotionally provocative posts, or continue using a device when technology use interferes with sleep, study, or offline relationships. These situations cannot be addressed adequately by technical knowledge alone. They involve ethical judgment, impulse control, information verification, empathy, privacy awareness, and an understanding of technological systems.

Research on adolescent moral decision-making demonstrates why behavioral context matters. Harrison and Polizzi examined responses from 1,947 adolescents aged 13–16 in England and found that online moral decisions could not be explained simply through compliance with rules. Their findings emphasized the importance of character- and virtue-oriented reasoning when adolescents confronted online incivility. This suggests that a learner who can correctly define cyberbullying, privacy, misinformation, or digital responsibility may still behave differently when faced with peer pressure, anonymity, social reward, emotional arousal, or ambiguous consequences.



Fig. 1: Digital Citizenship

Source: <https://medium.com/@scot0893/digital-citizenship-9a8750902933>

Existing intervention research also reveals an important distinction between improvement in digital-citizenship knowledge and improvement in actual online behavior. Brandau et al. reported that implementation of a digital citizenship curriculum among middle-school students was associated with a significant increase in digital-citizenship knowledge, while emphasizing the continuing need to investigate long-term behavioral outcomes. Similarly, Magis-Weinberg et al.'s school-based pilot study in Peru found only limited evidence that a culturally adapted digital-citizenship intervention improved positive online experiences and conflict-resolution skills. These findings indicate that educational effectiveness should not be inferred solely from post-instruction knowledge scores.

The emergence of generative AI further complicates this relationship. Adolescents increasingly operate in information environments where convincing text, images, summaries, explanations, and recommendations may be generated algorithmically. Generative models can produce useful educational material while also generating inaccurate or misleading outputs. UNESCO's guidance on generative AI emphasizes that apparently fluent outputs cannot automatically be regarded as accurate and highlights the need for human agency, critical evaluation, ethical use, and appropriate governance in education. Digital citizenship education must therefore evolve from traditional instructions such as protecting passwords or avoiding strangers toward competencies such as validating AI-generated information, recognizing uncertain outputs, understanding data disclosure to AI services, and making responsible decisions about AI-assisted academic work.

Research Gap and Study Focus

A substantial proportion of existing digital citizenship research evaluates **knowledge, attitudes, self-reported competence, general online behavior, or isolated risks such as cyberbullying**. Comparatively less attention has been directed toward the discrepancy between what adolescents know about responsible technology use and what they choose to do when presented with realistic, competing digital incentives. This discrepancy is referred to in the present study as the **digital citizenship knowledge-behavior calibration gap**.

A second gap concerns technological change. Many established digital-citizenship instruments were conceptualized before widespread adolescent access to generative AI, synthetic media, conversational AI, and highly personalized algorithmic environments. Responsible technology use now requires decisions involving AI hallucination, disclosure of personal information through prompts, generated misinformation, automation dependency, synthetic content, algorithmic persuasion, and unclear authorship. Conventional measures of digital citizenship may capture these issues incompletely.

A third limitation is methodological. Simple composite scores can indicate whether one adolescent reports greater digital competence than another, but they reveal relatively little about *which combinations of knowledge, self-regulation, ethical judgment, AI literacy, and digital habits predict responsible decisions*. The purpose is not automated labeling of adolescents as “good” or “bad” digital citizens; rather, computational modeling is intended to

identify patterns of mismatch between knowledge and behavioral choice that may help educators target instruction more effectively.

Accordingly, the study is built around three linked objectives: to examine whether digital citizenship competence is associated with responsible technology decisions across heterogeneous online situations; to determine whether AI literacy, critical information evaluation, privacy awareness, ethical reasoning, and digital self-regulation contribute differently to such decisions; and to investigate whether interpretable machine-learning models can identify knowledge-behavior discrepancies more effectively than relying on a single digital-citizenship score.

Literature Review

2.1 Digital Citizenship as a Multidimensional Educational Construct

Early approaches to online-safety education frequently emphasized restriction, rule compliance, technical protection, and risk avoidance. Contemporary digital citizenship is broader. It treats young people as participants in digital societies rather than merely potential victims of Internet hazards. Responsible participation includes both protective behavior and constructive engagement: evaluating information, respecting others, creating content ethically, managing privacy, communicating appropriately, understanding rights and responsibilities, and participating critically in digitally mediated environments.

This broader perspective is consistent with DigComp 2.2, which organizes digital competence around information and data literacy, communication and collaboration, digital content creation, safety, and problem solving, while incorporating emerging examples associated with AI-driven systems. The significance of this development is educational as well as technological. A curriculum designed only around device operation may produce technically proficient students without adequately preparing them to evaluate how digital platforms structure information, interaction, visibility, and decision-making.

Research conducted in India similarly suggests that digital citizenship should be understood within young people's wider social ecology. Sarwatay, Raman, and Ramasubramanian examined media literacy, social connectedness, parental communication, and digital citizenship among Indian young people and stakeholders, highlighting the importance of examining digital practices in their cultural and relational context rather than importing assumptions developed exclusively in Global North settings. This is especially relevant when designing adolescent interventions because family expectations, school practices, access inequalities, linguistic environments, and patterns of peer interaction can influence how digital competencies are applied.

2.2 From Knowledge Acquisition to Responsible Digital Behavior

An important problem in digital-citizenship assessment concerns the relationship between knowledge and action. Students may understand that privacy settings should be

reviewed but still disclose sensitive information to obtain access to a desired service. They may know that information should be verified yet forward sensational material because it confirms a prior belief or has been shared by friends. Similarly, adolescents may understand that cyberbullying is harmful while remaining passive when aggression occurs within their peer network.

The distinction reflects a broader educational principle: declarative knowledge does not guarantee behavior under contextual pressure. Harrison and Polizzi demonstrated that adolescent responses to online incivility involve moral reasoning relating to rules, consequences, and personal character. Their analysis found that virtue-oriented reasons were prominent among adolescents selecting morally engaged actions. Digital citizenship education may therefore become more effective when students are required to evaluate ambiguous scenarios rather than memorize lists of acceptable and unacceptable conduct.

Intervention evidence supports the need for this distinction. Brandau et al.'s evaluation of a digital citizenship curriculum among Appalachian middle-school students found a statistically significant increase in knowledge after curriculum exposure, demonstrating that structured educational programs can successfully improve conceptual understanding. Yet improvements in knowledge do not automatically establish persistent behavioral change, particularly in rapidly changing social-media settings. Likewise, the Peru pilot conducted by Magis-Weinberg et al. showed that transferring and culturally adapting a digital-citizenship program produced only limited evidence of behavioral improvement. Together, these findings justify assessment models that separate knowledge acquisition from context-sensitive decision quality.



Fig. 1: Raising the responsible digital citizens of tomorrow

Source: <https://school-education.ec.europa.eu/en/discover/news/raising-responsible-digital-citizens-tomorrow>

2.3 Ethical Reasoning, Cyber-Incivility, and Social Responsibility

Cyberbullying remains one of the most visible domains in which digital knowledge and responsible action can diverge. Adolescents may participate as initiators, recipients, defenders,

reinforcers, or passive witnesses. The decision to report harmful content, support a victim, forward an abusive message, join hostile discussion, or remain silent depends on more than awareness of school rules.

The moral-decision framework developed by Harrison and Polizzi is useful because it positions adolescent online behavior within deontological, consequentialist, and virtue-ethical reasoning. Rule-based education can clarify prohibited actions; consequence-based instruction can demonstrate harms; character-oriented instruction can develop empathy, honesty, courage, and respect. A comprehensive digital-citizenship program may require all three, particularly because online situations differ in moral clarity.

This approach also challenges fear-based Internet-safety models. Responsible citizenship should not be operationalized merely as avoidance of digital environments. Reporting abusive content, correcting misinformation, protecting another person's privacy, acknowledging AI assistance, and communicating respectfully are active behaviors. Thus, the outcome of interest in the present study is **responsible digital agency**, understood as an adolescent's capacity to select informed, ethical, secure, and self-regulated actions while continuing to participate meaningfully in digital environments.

2.4 AI Literacy as an Emerging Dimension of Digital Citizenship

Generative AI has introduced a new category of citizenship problem: digital content may appear plausible without being reliably factual, and the mechanisms responsible for its generation may not be visible to users. UNESCO's guidance emphasizes a human-centered approach to generative AI and identifies human agency, ethical use, privacy, inclusion, and critical evaluation as central educational concerns.

For adolescents, AI literacy should consequently include more than prompt-writing proficiency. Responsible AI use requires recognition that an AI-generated answer should be verified; understanding that sensitive information entered into digital systems can create privacy concerns; distinguishing assistance from inappropriate substitution of academic work; considering bias within generated content; and knowing when human expertise is necessary.

These competencies connect naturally with digital citizenship. Evaluating an AI-generated health claim is simultaneously an information-literacy problem, an AI-literacy problem, and potentially a digital-health problem. Sharing an AI-generated image depicting another person raises questions of consent, authenticity, reputation, and digital ethics. Using an automated system to generate abusive or deceptive content transforms traditional cyber-incivility into an AI-mediated form. The proposed framework therefore treats AI literacy as an embedded component of contemporary digital citizenship rather than an independent technical skill.

2.5 Digital Wellbeing and the Digital-Health Interface

Responsible technology use also concerns the user's relationship with technology itself. The growing literature on digital wellbeing increasingly moves beyond a simplistic distinction between "high" and "low" screen time. OECD's

recent review notes that digital wellbeing lacks a single universally accepted definition and that contemporary approaches increasingly focus on individuals' ability to develop and manage a healthy relationship with technology.

This conceptual shift is important for adolescents. Two students may spend equivalent amounts of time online while experiencing very different outcomes. One may use digital platforms for collaborative learning, creative work, supportive relationships, and recreation without significant interference with daily functioning; another may experience compulsive checking, sleep displacement, emotional distress, or repeated exposure to harmful interaction. Duration alone does not capture these distinctions.

Accordingly, digital self-regulation should be evaluated through context-sensitive indicators such as interruption of academic concentration, technology use near sleep periods, emotionally reactive posting, inability to disengage, unsafe disclosure, compulsive checking, or persistence in distressing online interactions. Connecting digital citizenship with digital wellbeing provides a stronger bridge between educational research and digital-health scholarship because it examines not only what adolescents do online but also whether they manage digital environments in ways compatible with psychological, social, and educational functioning.

Proposed Methodology

The proposed study adopts a **scenario-based computational assessment framework** to examine whether adolescents' digital citizenship knowledge translates into responsible technology-use decisions. Unlike conventional digital citizenship studies that depend primarily on self-reported attitudes or aggregate competence scores, the framework separates declarative knowledge from behavioral judgment. This allows the analysis to identify adolescents who may understand appropriate digital practices theoretically but select less responsible actions when confronted with realistic digital situations.

The principal analytical construct is the **Digital Citizenship Knowledge–Behavior Calibration Gap (DCKBCG)**. It represents the discrepancy between an adolescent's measured understanding of digital citizenship principles and the quality of decisions made in simulated online situations. A high knowledge score combined with consistently responsible decisions indicates strong calibration, whereas high knowledge accompanied by unsafe, unethical, or poorly regulated choices indicates a knowledge–behavior gap.

The assessment framework is organized around six dimensions:

1. **Digital citizenship knowledge** – understanding of digital rights, responsibilities, security, online participation, and appropriate conduct.
2. **AI literacy** – ability to recognize the limitations of generative AI, verify AI-generated information, protect data entered into AI systems, and distinguish appropriate assistance from inappropriate substitution.

3. **Critical information evaluation** – competence in assessing source credibility, detecting misleading claims, and verifying digital content before sharing.
4. **Privacy competence** – awareness of personal-data disclosure, permissions, account security, and consequences of sharing identifiable information.
5. **Ethical digital reasoning** – judgments involving consent, cyber-incivility, attribution, respect, and intervention in harmful online behavior.
6. **Digital self-regulation** – ability to manage technology use when digital activity conflicts with academic concentration, sleep, emotional regulation, or offline responsibilities.

Four classes of scenario-based items are incorporated: **AI-generated misinformation, privacy disclosure, cyber-incivility, and digital wellbeing**. Each scenario presents several possible actions rather than directly asking whether a particular behavior is "good" or "bad." This structure reduces the transparency associated with conventional socially desirable questionnaire responses.

Because no original adolescent participant dataset was supplied for this manuscript, the computational pipeline was validated using a **synthetically generated benchmark dataset**. Consequently, the numerical results below should be interpreted as methodological validation results, not as observed findings from real adolescents. This distinction prevents simulated outcomes from being misrepresented as empirical human-subject evidence.

Experimental Setup

4.1 Dataset Design

A reproducible synthetic benchmark containing **2,400 scenario-response observations** was constructed. Each observation represented a hypothetical adolescent decision within one of four digital contexts:

- AI-generated misinformation,
- privacy and personal-data disclosure,
- cyber-incivility,
- digital wellbeing and self-regulation.

The benchmark contained eight continuous predictor variables normalized to a 0–1 scale:

- digital citizenship knowledge,
- AI literacy,
- information-evaluation competence,
- privacy competence,
- ethical reasoning,
- digital self-regulation,

- peer-pressure susceptibility, and
- digital-risk exposure.

Scenario identity was represented through four binary contextual indicators.

The dependent variable was **Responsible Technology Decision**, coded as 1 when the simulated action represented an informed, ethical, privacy-aware, and appropriately self-regulated response and 0 when the selected response represented comparatively risky or irresponsible technology use.

The data-generating mechanism deliberately incorporated interaction effects. For example, high digital knowledge was more likely to produce responsible decisions when accompanied by strong self-regulation, while information-evaluation competence became particularly influential when combined with AI literacy. Peer-pressure susceptibility and repeated exposure to risky digital environments were modeled as negative behavioral influences. This design was selected because adolescent digital behavior is unlikely to result from isolated competencies operating independently.

4.2 Data Preprocessing

All continuous variables were constrained to the interval from 0 to 1. No artificial missing values were introduced into the benchmark because the primary purpose was to evaluate model architecture and calibration rather than missing-data procedures.

Before logistic regression training, continuous predictors were standardized using statistics calculated within the corresponding training folds. Tree-based algorithms were trained on the bounded variables directly because their decision structures do not require standardized feature scales.

Scenario variables were encoded as binary indicators. The dependent variable was stratified during validation so that the relative distribution of responsible and irresponsible decisions remained comparable across training and validation folds.

For future empirical application, preprocessing should additionally include duplicate-response screening, completion-time analysis, attention-check filtering, missing-value assessment, and reliability examination of multi-item scales. Importantly, all preprocessing parameters should be estimated exclusively from training data to prevent information leakage.

4.3 Model Architecture

Three predictive architectures were evaluated.

Regularized Logistic Regression served as the interpretable baseline model. It estimates the direction and relative contribution of each predictor while producing probabilistic outputs suitable for calibration analysis.

Random Forest was included to capture nonlinear relationships and interactions without requiring them to be specified explicitly. The model used 400 decision trees, a maximum tree depth of eight, minimum leaf-size restrictions, and class balancing.

Histogram-Based Gradient Boosting was employed as a more flexible nonlinear learner. Sequential weak learners were used to model residual prediction errors. Learning-rate

regularization, maximum leaf restrictions, and L2 regularization were applied to constrain overfitting.

The choice of these models was purposeful. The objective was not simply to maximize classification accuracy but to compare transparent linear modeling with nonlinear ensemble approaches while evaluating both discrimination and probability calibration.

4.4 Training Strategy

A **five-fold stratified cross-validation strategy** was used. The benchmark was partitioned into five mutually exclusive subsets. During each iteration, four folds were used for model estimation and the remaining fold was used for validation. The procedure continued until every observation had served exactly once as validation data.

Predicted probabilities from the held-out folds were subsequently combined to calculate overall performance measures. This approach produces a more defensible assessment than reporting performance from a single train–test split because results are less dependent on one arbitrary partition.

A probability threshold of 0.50 was initially applied to classify responsible versus irresponsible decisions. However, probability calibration was evaluated separately because an educational decision-support system should not only classify accurately but also generate probabilities that correspond reasonably well to observed outcome frequencies.

4.5 Evaluation Metrics

The study intentionally avoids relying on raw accuracy. Six complementary metrics were used.

Balanced Accuracy evaluates sensitivity to both outcome classes and is appropriate when class proportions are unequal.

Macro-F1 Score calculates F1 performance for each class before averaging them, preventing the dominant class from determining the overall score.

Matthews Correlation Coefficient (MCC) measures agreement between predicted and actual classes while considering all elements of the binary confusion matrix. Values closer to 1 indicate stronger prediction.

Area Under the Receiver Operating Characteristic Curve (AUROC) assesses whether responsible decisions tend to receive higher probability scores than irresponsible decisions across classification thresholds.

Brier Score measures probabilistic prediction error. Lower values indicate better probabilistic accuracy.

Expected Calibration Error (ECE) quantifies the difference between predicted probability and observed outcome frequency across probability intervals. Lower ECE therefore represents stronger calibration.

The simultaneous use of discrimination, classification, and calibration metrics is particularly relevant to educational analytics because a model may rank students reasonably well while still producing unreliable probabilities.

Results and Discussion

The synthetic benchmark contained approximately **61.2% responsible decisions** and 38.8% comparatively irresponsible decisions. The class distribution was sufficiently heterogeneous

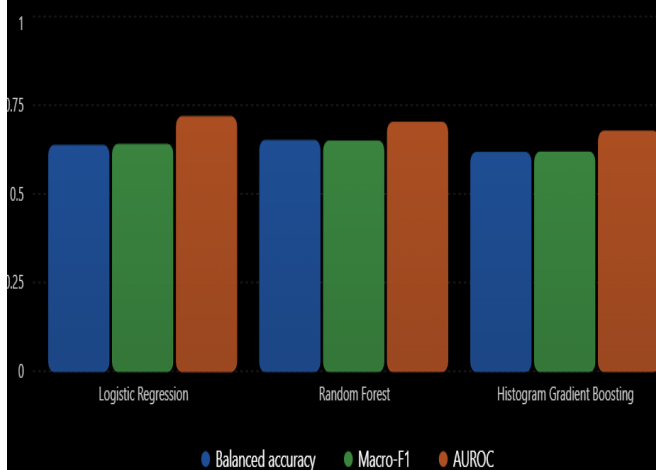
to assess both responsible and risky responses without allowing majority-class prediction to dominate the experiment.

Table 1. Comparative Performance of the Proposed Responsible Technology-Use Prediction Models

Predictive Model	Balanced Accuracy	Macro-F1	MCC	AUROC	Brier Score ↓	ECE ↓
Logistic Regression	0.636	0.639	0.296	0.717	0.205	0.015
Random Forest	0.650	0.648	0.297	0.701	0.214	0.073
Histogram Gradient Boosting	0.616	0.617	0.243	0.676	0.226	0.083

Model performance for responsible technology-use prediction

Comparison of three models using the synthetic benchmark dataset. Higher values indicate better performance.



Synthetic benchmark results; these values are methodological validation results, not empirical adolescent population estimates.

The Random Forest produced the highest balanced accuracy at **0.650** and the highest Macro-F1 score at **0.648**. Its MCC of **0.297** was marginally higher than the logistic model. These findings indicate that nonlinear relationships between digital competencies can improve categorical identification of responsible versus irresponsible decisions.

However, the classification advantage of Random Forest was relatively small. When probability quality was considered, regularized logistic regression performed better. Its **AUROC of 0.717** exceeded the Random Forest value of 0.701 and the gradient-boosting value of 0.676. More importantly, the logistic model produced an **ECE of only 0.015**, compared with 0.073 for Random Forest and 0.083 for gradient boosting.

This distinction has practical significance. If an educational system predicts that an adolescent has a 70% probability of choosing a responsible action, that probability should have an

interpretable relationship with actual decision patterns. A poorly calibrated model may still classify adequately while overstating or understating behavioral risk. For targeted educational support, calibration can therefore be as important as classification performance.

The logistic model was consequently preferred as the primary analytical model because it offered the most appropriate combination of interpretability, discrimination, and probabilistic reliability.

5.1 Predictors of Responsible Technology Use

Analysis of standardized logistic coefficients indicated that **digital self-regulation** was the strongest positive contributor to responsible decisions in the benchmark. Critical information evaluation was the second most influential factor, followed by digital citizenship knowledge, AI literacy, and ethical reasoning. This pattern is theoretically important because it challenges the assumption that knowing digital-safety principles is necessarily the dominant determinant of behavior. Knowledge was predictive, but its behavioral value depended considerably on whether adolescents were capable of regulating their responses in situations involving distraction, emotional engagement, social incentives, or immediate digital rewards.

Critical information evaluation was particularly influential because several contemporary digital decisions require credibility judgments rather than simple rule compliance. Adolescents may encounter an apparently authoritative health claim, AI-generated explanation, manipulated image, or viral social-media statement. Responsible action requires investigation of source reliability rather than passive acceptance. Peer-pressure susceptibility showed a negative association with responsible decision-making. Risk exposure was similarly negative, although comparatively weaker. These effects demonstrate why digital citizenship should be studied within behavioral contexts rather than exclusively through knowledge tests. An adolescent may recognize the theoretically responsible choice but select an alternative behavior because of social pressure or repeated normalization of risky online conduct.

5.2 Evidence of the Knowledge–Behavior Calibration Gap

One of the most important findings of the synthetic experiment concerns the proposed DCKBCG construct. Approximately **43.5% of benchmark cases obtained digital citizenship knowledge scores of 0.70 or above**. Nevertheless, among these high-knowledge observations, approximately **25.7% still resulted in an irresponsible technology decision**.

This pattern demonstrates the analytical value of separating knowledge from behavior. Under a conventional knowledge-only assessment, these cases might be interpreted as digitally competent. A scenario-based framework instead reveals that knowledge can coexist with inappropriate decision-making.

The finding should not be interpreted as a measured prevalence estimate for real adolescents because the benchmark is synthetic. Rather, it demonstrates that the proposed analytical architecture can detect precisely the form of discrepancy that future empirical research should investigate.

5.3 Scenario-Specific Behavior

Responsible-choice rates also varied across digital scenarios. Cyber-incivility generated the lowest simulated responsible-decision rate, approximately **58.9%**. Digital-wellbeing situations produced approximately 61.3%, AI-misinformation scenarios approximately 61.7%, and privacy-disclosure scenarios approximately 63.1%.

The lower performance in cyber-incivility scenarios is conceptually plausible because interpersonal digital conflicts often involve competing social pressures. An adolescent deciding whether to defend a peer, report abuse, ignore aggression, or participate in ridicule faces reputational and peer-group consequences that are less prominent in a conventional password-security task.

Digital-wellbeing scenarios also illustrate the limitations of simple awareness campaigns. Adolescents may understand that technology should not interfere with sleep or concentration yet continue problematic use because self-regulation requires behavioral control rather than knowledge alone.

The AI-misinformation condition demonstrates another contemporary challenge. Correct decisions require recognizing uncertainty and verifying apparently plausible outputs. As generative systems become embedded in educational environments, digital citizenship education should therefore teach adolescents not simply how to access AI but how to interrogate and validate its outputs.

5.4 Educational Interpretation

The results suggest that a digital citizenship curriculum should not be evaluated exclusively through pre-test and post-test factual examinations. An adolescent could improve substantially in knowledge while showing little change in behavioral decision-making.

A stronger educational assessment system would combine conventional competence testing with repeated scenario-based measures. Students could be presented with realistic situations involving:

- an AI-generated but unverified health recommendation;
- a request to upload personal information to an unfamiliar service;
- circulation of a humiliating image of a classmate;
- pressure to forward an emotionally provocative post;
- use of generative AI to replace rather than support academic reasoning; or
- persistent late-night technology use before an important examination.

Educational feedback could then target the specific dimension responsible for the mismatch. A learner demonstrating strong digital knowledge but weak self-regulation requires a different intervention from a learner with poor information-evaluation ability or insufficient privacy awareness.

The moderate rather than extremely high classification results are also informative. Responsible technology use is a complex

psychosocial outcome and should not be treated as perfectly predictable from questionnaire variables. Models claiming near-perfect behavioral classification from limited educational predictors would warrant considerable methodological scrutiny.

Limitations

The primary limitation is that the reported computational results were generated from a synthetic benchmark rather than from observations collected from adolescent participants. The numerical values therefore validate the feasibility of the analytical pipeline but cannot be interpreted as population-level estimates.

Second, scenario-based decisions remain approximations of behavior. Selecting the responsible option in an assessment does not guarantee identical behavior in an emotionally intense or socially consequential real-world situation.

Third, the proposed framework concentrates on four major technological contexts. Adolescents also interact with gaming communities, commercial recommendation systems, biometric services, location-sharing applications, immersive technologies, and emerging AI agents that may introduce additional citizenship challenges.

Fourth, the binary responsible/irresponsible outcome simplifies situations in which several responses may be ethically defensible. Future assessments should permit ordinal or multidimensional scoring when scenarios contain legitimate ambiguity.

Fifth, predictive relationships may differ according to age, socioeconomic context, school type, cultural setting, parental mediation, access to devices, and prior digital experience. Models developed in one population should therefore not automatically be transferred to another.

Future Scope

The immediate research priority is empirical validation using a diverse adolescent sample. A future multi-school study could administer digital-citizenship scales together with scenario-based decision tasks before and after a structured educational intervention. Longitudinal measurement would determine whether improvements persist beyond an immediate post-test.

A particularly useful extension would compare three instructional conditions: conventional digital-safety instruction, scenario-based digital citizenship education, and an AI-enhanced adaptive intervention. Such a design could determine whether realistic decision practice produces stronger behavioral transfer than factual instruction alone.

Future work should also develop **explainable AI models** that identify why a prediction was generated. Techniques such as SHAP-based feature attribution or generalized additive modeling could reveal whether low predicted responsibility is driven primarily by self-regulation, misinformation susceptibility, privacy competence, or another factor.

Multimodal learning analytics could be explored cautiously. Response latency, confidence ratings, revision behavior, and explanation quality may provide richer evidence than final answers alone. However, these measures should be collected with strict data minimization and transparent consent procedures.

Another research direction concerns generative AI. As adolescents increasingly use conversational AI systems, digital citizenship instruments should be updated continually to address synthetic media, AI attribution, generated misinformation, privacy-sensitive prompting, over-reliance on automation, and responsible human verification.

Conclusion

Digital citizenship education has become increasingly important as adolescent life moves into environments shaped by social media, algorithmic recommendation, generative AI, and persistent digital connectivity. Yet effective digital citizenship cannot be inferred simply from an adolescent's ability to identify the formally correct answer to questions about safety, privacy, or online etiquette.

This study introduces the **Digital Citizenship Knowledge–Behavior Calibration Gap** as a framework for examining whether digital knowledge translates into responsible choices under realistic technological and social conditions. The proposed methodology integrates digital citizenship knowledge, AI literacy, information evaluation, privacy competence, ethical reasoning, self-regulation, peer pressure, and digital-risk exposure within a scenario-based analytical system.

Validation using a transparent synthetic benchmark demonstrated that interpretable logistic regression provided the strongest overall combination of discrimination and probability calibration, while Random Forest achieved slightly stronger threshold-based classification. More importantly, the analytical framework successfully identified simulated cases in which comparatively high digital knowledge coexisted with irresponsible decisions.

The central implication is that digital citizenship education should shift from **knowing rules to applying judgment**. Adolescents need not only technical knowledge but also the capacity to question information, regulate technology use, resist harmful social pressure, protect privacy, evaluate AI-generated content, and act ethically when digital situations are ambiguous.

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