

<https://doi.org/10.59298/NIJLCL/2026/6.2.180000>

AI Literacy and Civic Resilience: Curriculum Models and Evaluation

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ABSTRACT

The rapid advancement of Artificial Intelligence (AI) has significantly transformed social interactions, education, governance, and decision-making processes, while also introducing complex challenges relating to misinformation, algorithmic bias, inequality, and digital participation. This study examines the relationship between AI literacy and civic resilience by exploring curriculum models and evaluation approaches that prepare learners to engage responsibly with AI-driven societies. AI literacy is conceptualized as the combination of knowledge, skills, and dispositions required understanding, using, and critically evaluating AI systems, while civic resilience refers to the capacity of individuals and communities to participate effectively in democratic processes through informed decision-making and ethical engagement. The study reviews key curriculum models, including inquiry-based, competency-based, interdisciplinary, and culturally responsive approaches, highlighting their potential to develop critical thinking, creativity, ethical reasoning, collaboration, and digital citizenship. It further examines evaluation frameworks that incorporate formative and summative assessments, outcome measurement, validity, reliability, equity considerations, and data-informed program improvement. The paper also discusses implementation factors such as policy alignment, teacher professional development, resource accessibility, and the ethical, legal, and social implications of AI integration in education. Findings indicate that effective AI literacy education requires a shift from purely technical instruction toward holistic approaches that connect technological understanding with civic responsibility. Integrating AI literacy with civic resilience can empower learners to navigate digital environments, challenge algorithmic inequalities, participate in democratic discourse, and contribute to inclusive and responsible technological development.

Keywords: Artificial Intelligence Literacy; Civic Resilience; Curriculum Models; Digital Citizenship; and Educational Evaluation.

INTRODUCTION

The rapid development of Artificial Intelligence (AI) and its dissemination into culture raise unexpected societal challenges that threaten social cohesion [1]. The overarching aim of this study is to assess curriculum models addressing AI literacy and their contributions to civic resilience, defined as the capacity of individuals and communities to participate in democratic processes through informed decision-making [2]. Various theoretical lenses highlight the social implications of AI, especially on marginalized groups and cultural diversity [3]. To offer enhanced programmability of learning progression and clearer opportunities for design-based research, a broad definition of AI literacy is adopted, encompassing knowledge, skills, and dispositions. Civic resilience is similarly defined as a combination of competencies enabling individuals to engage as informed citizens and digital natives [4]. The emphasis on participation and the potential for both national and local curricula to nurture democratic values further motivate the choice of civic resilience rather than related concepts such as democracy or digital citizenship [2]. Contemporary conditions in society and education, spurred by external crises and the pervasive integration of digital technologies, underscore the importance of AI literacy and civic resilience [1]. The reconfiguration of learning goals arises amidst the global quest for improved educational systems and the quest to

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ensure safe, ethical, equitable, and effective AI use. Learning objectives centring on data-related topics have gained particular traction [1].

Conceptual Foundations of AI Literacy and Civic Resilience

The increasing reliance on artificial intelligence (AI) and the growing impact of algorithmic systems on society necessitate equipping citizens with basic knowledge and understanding of AI in addressing societal challenges. AI literacy comprises knowledge, skills, and dispositions to comprehend and engage with AI and its societal implications as a foundation for informed and active civic participation [1]. Civic resilience consists of knowledge, skills, attitudes, and values that enable individuals to participate in the digital society in an informed manner, evaluate the adequacy of algorithmic systems, and deliberate on ethical and social implications [2]. AI literacy and civic resilience are interrelated: the lack of AI literacy, algorithmic biases, and other societal inequities create unjust challenges for equitable digital participation and hinder access to both knowledge and societal voice. Technology-rich learning environments fostering critical thinking, innovation, collaboration, and knowledge synthesis are core aspects [3]. These competencies reflect deeper socio-technical frameworks of AI and wider macro-level data subject areas. Networking and representation as parameters refer to interrelation among disparate data and their structural depiction, respectively; the socio-technical model guides understanding of socio-technical systems, especially service-oriented society; and balancing data sharing, community fostering, and quality assurance [4].

Curriculum Models for AI Literacy

Interest in artificial intelligence (AI) education has surged in recent years, paving the way for educators, curriculum developers, and researchers to create early-stage AI curricula for primary and secondary education worldwide [5]. A variety of frameworks now support the design of AI literacy initiatives, and numerous open-access resources and curricula have emerged [1]. At the same time, the global urgency of AI-related challenges such as algorithmic bias, misinformation, and digital surveillance, presses the education community to clarify the knowledge, skills, and attitudes necessary for informed and responsible civic participation in a datafied society [4]. Despite the rapid growth of AI literacy initiatives, the frameworks and curricula presently in circulation rarely address these pressing issues, nor do they explicitly consider the concept of civic resilience [6]. An exploratory review of existing AI literacy frameworks and curricula highlights the need for consideration of civic-resilience competencies while also pointing to the potential of theoretical lenses such as the 4Cs of 21st-century education, the Student Career and Academic Planning framework, and culturally sustaining pedagogy [7].

Inquiry-Based Curricula

AI literacy and civic resilience are both critical topics for education in digital societies. AI literacy refers to knowledge of AI systems and algorithms together with the ability to use, critique, and make decisions on them [8]. Civic resilience is the capacity to participate in public deliberations, exercise digital citizenship, and reflect on ethical questions [9]. The two are closely intertwined: algorithmic systems impact social interactions, and participation with them requires ethical thinking about their use [2]. Local, national, and global policy is also affected by AI [1]. Given educational institutions' role in preparing students for productive participation in such matters, AI literacy and civic resilience have emerged as key components of contemporary education [1].

Competency-Based Frameworks

Competency-based approaches to AI literacy are emerging in various educational contexts. The framework encompassing "Artificial Intelligence Literacy" developed by multiple universities targets learners from age 10 to adults [4]. The goal of AI literacy is to avoid the double lock of data poverty and data coloniality by promoting equitable data accessibility and putting data at the centre to enable effective and trustworthy civic engagement on a global scale [5]. This framework emphasizes the development of four capabilities: empathy, judgements, curiosity and design [1]. Similar concepts of literacy can be found in other disciplines such as financial literacy, media literacy, environmental literacy, climate literacy, and data literacy, but the concept of AI literacy differs fundamentally from the conventional notion of literacy [6].

Interdisciplinary Integrations

In elementary and secondary education, many AI curricula have sought to enhance learning through interdisciplinary integrations or connections to other subjects. Transdisciplinary AI education extends beyond the integration of several subjects to address complex real-world problems through collaboration across disciplines [3]. Teachers from different subjects work in concert, thereby ensuring that AI is included as part of broader learning rather than in isolation [4]. This approach highlights the interconnectedness of knowledge and the importance of addressing issues that span multiple fields, encouraging students to view AI as a tool for understanding and tackling real-world challenges [5]. In parallel, various frameworks for AI literacy have emerged [1]. The AI Competency Framework for K–12 Education in Canada identifies the concepts of data, AI systems, and AI society; specifies a competency-development continuum with three proficiency levels; and describes expected achievements associated

with each level. The AI4K12 initiative in the United States organizes AI topics into five big ideas and eight practices [6].

Culturally Responsive Approaches

Curriculum frameworks emphasize students' cultural backgrounds, identities, and lived experiences [1]. Recognizing that learning is theory-laden and culturally mediated, these frameworks support culturally responsive approaches [2]. Language-in-education policies often articulate contemporary Spanish-language educational practices across the education system [3]. Models in language and school system policies define procedures and the educational expectations in the languages used. School policies, regulatory rules and institutional provisions articulate mono-, bi- or plurilingual provisions for the provisions adopted across educational zones, regions or areas [4].

Evaluation frameworks for AI literacy curricula

A comprehensive evaluation framework can help curriculum designers consider the interrelated components that contribute to a successful AI literacy curriculum [1]. Such a framework provides a holistic view of the design process, enabling informed decisions about curriculum model selection and adaptation. Formative assessment approaches applied within AI literacy curricula prioritize the enhancement of learner knowledge, skills, and dispositions, with an emphasis on the learning process [2]. Curricular enactments can be intentionally supported with pedagogical strategies generating learner artefacts and reflections. These outputs, aligned with established, desired curricular competencies, can thus inform iterative design refinements [3]. Summative evaluation approaches related to the broader impact of AI literacy curricula measure the extent to which the curriculum has produced the intended programme outputs and attained the expected competencies. Outcome measures evaluate post-curricular shifts in learner knowledge, skills, and dispositions as a result of previously determined curricular enactments [4]. Capturing humanistic or socio-technical phenomena difficult to quantify remains complex, but diverse understandings and conceptions provide alternative angles for appraisal. The necessity for ongoing validation and calibration of curricular enactments remains paramount. A systemic life-cycle approach for data collection, analysis, and reporting enables design teams to expand their situational understanding over time [5].

Formative Assessment Strategies

The role of formative assessments in evaluating AI literacy and civic resilience curricula is to provide feedback that informs ongoing development of curricula and pedagogy in a continuous improvement cycle, rather than to furnish a final appraisal of implementation [6]. Multiple frameworks exist to characterize the implementation of or response to curricula addressing AI literacy or civic resilience, allowing adopters to map their curricular materials and approaches to existing guidelines, rubrics, models, or inventories designed by other authors [7]. Some frameworks outline the competencies or dimensions envisioned as goals for students, while others encapsulate details of the proposed learning experiences themselves [8]. Other strategies center on gathering feedback from students, teachers, and other stakeholders following a curriculum pilot, using surveys, interviews, focus groups, or other tools to explore perceptions of importance and adequacy associated with the curriculum's objectives, content, and pedagogical strategies [9]. Such data may indicate whether the emphasized competencies and dimensions align with student needs and inform revisions of the curriculum toward tighter fit [2]. Finally, additional evaluative instruments examine learning outcomes for evidence of attainment that indicates a proportionate contribution to student AI literacy, civic resilience, or both [1]. Such measurements assess evidence of curricular effectiveness after it has already been implemented, rather than informing activity selection during initial development; they provide an account of what students have learned, rather than what is proposed for them to learn [1].

Summative Evaluation and Outcome Metrics

Evaluating the effectiveness of educational programs requires both summative evaluation and clear specification of metrics [1]. Curriculum developers need to articulate the skills that their instruction will foster and determine and choose appropriate tools for measuring progress [2]. A set of outcome metrics may be formulated based on the expected competencies highlighted in Section 4.2. Outcome metrics specific to AI literacy should take precedence, but broader competencies connected to civic resilience, digital citizenship, ethics, responsible media use, and other related constructs are also relevant and may facilitate cross-sector funding. AI literacy and civic resilience are interrelated constructs, and the overlap between the two highlights important principles. AI literacy includes knowledge and skill areas such as AI definitions, societal implications, responsible use, critical examination, and participatory alternatives. Civic resilience comprises digital citizenship, media production, systems thinking, privacy, and data discourse. Final project evaluation should encompass multiple AI literacy areas alongside selected civic resilience areas. Many AI-literate students seek to act socially responsibly, and some address issues of equitable access and related media-production tools in their projects. Engagement with these issues can be fostered through freely available media-creation and project-development platforms such as Microsoft Paint, Canva, WeVideo, and Voki.

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Validity, Reliability, and Equity Considerations

A curriculum dedicated to AI literacy will most likely have a high degree of user variability, in terms of conditions, experiences, and competences [5]. The design of user-friendly and initially adaptable components allows the gradual addition of sophistication and the avoidance of “one-fit”-approaches. Implicitly based on a reference model of systematics of AI literacy peripheral components can be added flexibly [6]. Fundamental top-figure pattern recognition (“anomaly detection”) within text, information, image, and sound, supported by examples from freely available material readily accessible via the Internet, provides the basis for a broad spectrum of interdisciplinary approaches [7]. Early introduction of the “discrimination dimension” familiarizes language and culture users with behaviour conflicting with good practice and discourages overconfidence as well as regulation avoidance. Inputs and impulses enabling cross-checking of AI-generated material are close at hand; layers requiring extensive skill enhancement can be postponed at will [8]. The curriculum under development, continuously tested through pilot applications, adds a competence dimension to conventional literacy 1.0 and 2.0 approaches and embeds conventional systems within the learning of (semi-)automated materials [9]. Digital handling of conventional and (semi-)automated texts remains optional. Multi-disciplinary exposure could stimulate cross-pollination [1]. The development of cross-disciplinary and cross-informal learning material, including text material on integration of AI in pedagogical practice, aims to assist AI literacy enhancement in parallel to curriculum roll-out; the latter relies on both broad technical access and topical interest [2]. Ongoing discussions keep pedagogical stakeholders involved and provide a shared perspective to counteract “Syllabus V” occurrences [1]. The highly topicality-dependent nature of inputs opens routes towards immediate classroom inclusion; adaptation to publication-standards does not impede the integration of current developments. Awareness of systemic vulnerabilities invites the contemplation of design options supporting legislative-action avoidance [4].

Data-Informed Program Improvement

Data-informed program improvement focuses on curriculum implementation and iterative adaptation, augmenting program planning with evidence-based feedback loops and quality assurance mechanisms [3]. Based on three national, two from Hong Kong and one from Singapore curriculum initiatives at the K-12 and higher education levels, three overlapping aspects inform the continuous improvement of AI literacy programs: the collection and analysis of student data, the assessment of teacher competencies and satisfaction, and the monitoring of social, political, technological, and cultural developments affecting implementation [4]. These factors link the analysis of local implementation to broader local, regional, and global contexts [5].

Implementation Considerations for Diverse Educational Contexts

The preceding sections of the report have outlined curriculum models and associated evaluation frameworks aimed at developing AI literacy and civic resilience [2]. This section articulates a set of implementation considerations to assist in tailoring these models to diverse national, regional, institutional, and community contexts [3]. Four such considerations emerge as particularly salient: alignment with existing education policies and governance structures; preparation and ongoing professional development of educators responsible for AI literacy and civic-resilience curricula; availability and accessibility of resources, including materials, tools, and physical or digital learning spaces; and attention to ethical, legal, and social implications of AI in ways that local contexts deem appropriate [1]. Additional guidance concerning implementation at specific geographic levels national, regional, institutional, and community is also available in the literature [4]. By situating newly emerging curriculum models and evaluation frameworks within existing education policies and governance frameworks, educators and education stakeholders increase the likelihood that implementation efforts will align with pertinent mandates and expectations [5]. Furthermore, centring models on one or more of the United Nations Educational, Scientific and Cultural Organization’s four pillars of education, learning to know, learning to do, learning to live together, and learning to be may also enhance congruence with prevailing policy orientations and visions of educational equity [6].

Policy Alignment and Governance

AI literacy is an emerging area of educational research and practice, with an accelerating number of pedagogical proposals at all levels of education, from kindergarten to university, and across numerous domains, including ethics, the social sciences, and the arts [4]. Writing in 2020, Zhou et al. noted that AI literacy has gained increasing attention from educators, researchers, and policy-makers worldwide. Several countries have embarked on new initiatives to integrate AI topics into their curricula for students of all ages [5]. Nevertheless, the first wave of initiatives in many regions has tended to focus narrowly on a few subjects, especially the technical aspects of how AI works. Current teaching and learning resources often remain fragmented, and substantial opportunities remain for wider curricular integration in line with emerging international trends [6]. Civic resilience, meanwhile, refers to the capacities of individuals to participate meaningfully and responsibly in civic life through informed engagement, ethical reasoning, and judicious investment of attention in an increasingly complicated and contested information environment [7]. Public discourse increasingly takes place in digital environments, fostering

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opportunities for civic participation yet also amplifying misinformation, micro-targeted disinformation campaigns, and hostile rhetoric [4]. Even as students gain more freedom over the content they encounter within a formal curriculum, the stakes of participation in public discourse have seldom been higher. Preparing them to navigate this environment therefore constitutes a clear priority for education [5]. The curricular landscape that addresses AI topics remains expanded and complex, as do the implications for the specific forms of civic literacy and resilience needed in relation to the presence and diffusion of AI technologies, from generative chatbots to deep fake [1].

Teacher Preparation and Professional Development

Research with educators in diverse locations indicates that teachers incorporate AI literacy as a component of citizenship education, ethics, data-driven decision-making, and digital literacy [4]. Preparation programs emphasize knowledge of educational technologies and pedagogical techniques to leverage these digital tools for improving student learning [1]. Since assistance for equity-focused AI curriculum design and integration remains scarce in formal pedagogical training, collaborative efforts among local and global partners strive to develop new resources that engage policymakers and influencers [5]. Policy perspectives on fostering strategic, inclusive access to AI and supporting school staff through the curriculum creation process may also shape AI literacy [6].

AI literacy efforts often intertwine with civic engagement initiatives to promote informed participation in social issues. Organizing institutions select projects aligned with these themes, enabling integration of awareness, criticality, and agency into instruction [5]. Educators engage students in discussions of algorithmic bias, bias in large language models, AI's environmental footprint, anti-bias strategies, and the ethics of AI-assisted writing. Design of the AI curriculum builds on existing knowledge of algorithmic bias and digital citizenship [6].

Resource Availability and Accessibility

In many curricula, AI tools are widely adopted, but the teaching of their implications, limitations, and social consequences lags far behind [1]. Mathematical, computational, and data sciences are core to the AI curriculum, yet they remain underdeveloped in K–12 education. Limited curricular time compounds various other difficulties to deliver a systematic program of AI literacy that encompasses the intent and spirit of many documents [3]. Equitable access to software tools influencing pupil learning remains a key barrier to AI literacy implementation. Many effortfully developed tools are published in new software environments [2], reflected in the relatively small number of educational programs listed on the AI4K12 (<https://ai4k12.org>) model. Efforts from various agencies may be directed towards integrating K–12 AI education into the subject-matter areas covered in existing programmes [3]. Until comprehensive mathematics benchmarks are established, those already articulated would beneficially welcome enhanced alignment with AI principles [4].

Ethical, Legal, and Social Implications

Public discourse regarding AI has become charged with polarizing terms like “intelligence,” “bias,” and “overhyped [1].” These terms point to profound ethical and political issues. Among the most prominent ethical issues are surveillance and privacy; bias and discrimination; misinformation; manipulation; security; and public accountability of automated systems [6]. These issues impact K–12 students' lives because, as research shows, young people are often heavy consumers and creators of media online, making candidates for manipulative messaging [7]. Moreover, digital platforms and algorithmic systems increasingly shape their educational and employment opportunities, warranting understanding at the level of digital citizenship and internet control [8]. Each AI technology advancing toward capabilities anticipated of a “general” AI poses sociocultural impacts to childhood freedoms, ethics of cultural appropriation, capacity for creative applied arts, and misconceptions about an “artificial” life [9]. The ethical discussion remains disconnected from pedagogical practice where AI has entered education, pointing to learning opportunities. Gender stereotypes, school trust, data privacy, and teacher-student relationship biases are still discussed in AI and speech technologies [4]. Ethical considerations remain embedded in design frameworks for K–12 curricular integration of AI pedagogies [1] and yet are absent from reviews of inquiry-based AI pedagogies. Despite calls for including ethical discussions, entering education remains limited to content and jargons of narrow or general AI models and creative combinations of words without explicit attention to actual consequences, a point where the pedagogical need emerges [2].

Case Studies and Comparative Analyses

Artificial intelligence (AI) literacy as an emerging educational focus has captured educators' attention internationally. AI literacy encompasses understanding key AI concepts, data practices, and the social implications of AI technologies [2]. These challenges are considered critical curricula by several jurisdictions, including UNESCO and OECD, and resonate widely across jurisdictional boundaries [3]. Given these global trends, it is important to identify existing educational initiatives that address AI literacy along with corresponding evaluation frameworks, to better understand their scope, strengths, and limitations. Such insights can inform AI literacy development across different learning contexts. A preliminary scan was undertaken to identify existing AI literacy initiatives [4]. Three complementary processes provided insights into potential AI literacy programmatic and

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curricular foci: a public search of open AI curriculum materials; a review of K-12 AI curriculum documents, publicly available standards documents, and supporting resources; and an AI literacy-focused analysis of the Canadian 2019 curriculum [5]. Following the preliminary scan, a systematic investigation of additional AI literacy-related initiatives was carried out a supplement to the program's consideration of AI literacy and data governance [6]. These initiatives span various government, non-profit, and private entities from diverse countries, addressing educational issues and challenges beyond AI literacy. Various formal educational levels are represented (primary, secondary, post-secondary), though the majority focus on secondary and post-secondary settings [7]. Within the primary and secondary sector, programs take different forms government-led, non-profit-supported, and school district-driven. Community partnerships and complementary AI literacy initiatives are also explored [2].

National and Regional Initiatives

The current section surveys national and regional initiatives embedding AI literacy in school curricula across Canada, Finland, France, New Zealand, Singapore, and the United Kingdom, as well as investigations nationwide, by sector, and within jurisdictions such as Alberta that resonate with the practice-oriented emphasis of the present model [3]. Unlike complementary K-12 guidelines concerning AI education [1], these frameworks do not exemplify AI literacy. Broader around AI in society [2] yet overlapping, such guidance continues to inform other proposals. In parallel, teacher preparation inquiries targeting AI, data science, and digital literacy reinforce curricular, instructional, and educational-development necessity [4].

School-and District-Level Implementations

The state and the province of Ontario have investigated the relationship between AI and education and have recognized the need for AI literacy as part of educational tools and remaining informed citizens [7]. The Ministry of Education of the province of Ontario has published the "Artificial Intelligence and Education Project" as one of the "Ontario AI Strategy" initiated in 2018 and has promoted AI literacy and development of tools and guidelines for school boards [1]. Under the project framework, AI at the Core defines a set of considerations and provides recommendations for the ongoing development of AI-related initiatives and educational programing undertaken at the provincial, regional, and local levels [8]. Two focal points of the measures are dedicated to the important role of AI in primary and secondary education through the development AI curricula and enhanced AI learning opportunities [9]. The Ontario AI Strategy aims to build a regional AI sector ecosystem and strengthen Ontario's leadership in the global AI field, while the AI at the Core project aims to inform the role of AI in primary, secondary, and postsecondary education [6]. The initial stage of the project was initiated by the Ministry of Education in 2019 and the release of a report titled "Artificial Intelligence and Education Overview". Following the review of AI-related initiatives in the province and other countries, the report recognized AI literacy as a core component of AI education [5]. The development of infrastructure, guidelines, and implementation support for AI curricula in K-12 education was identified as a primary issue [1].

Community-based Partnerships

Community-based partnerships can foster AI literacy by connecting learning to issues that matter to participants. Some programs collaborate with communities to integrate learners' interests and aspirations into teaching, encouraging exploration of local challenges [7]. Partnerships can offer additional resources, broaden the audience for student work, and provide feedback from practitioners [8]. They may enhance retention and relevance by anchoring learning in communal challenges [9]. Literacy programs may follow the tradition of service-learning by addressing community needs while developing AI skills. When engaging underserved youth, integrating community contexts including assets and priorities, strengthens local focus. Involvement of families, recognized as agents for student success, can further extend reach [1].

Challenges, Gaps, and Research Directions

AI and algorithm literacy is broadly reflected in curricula addressing general concepts of AI, data science, or critical digital skills, which often go beyond students' own experience of AI technologies [7]. Many AI curricula emphasize technical knowledge and skills (e.g. programming, machine learning), whereas literacy also involves understanding implications [1]. Curricula are missing that bring together AI and citizen engagement; that explore algorithmic decision-making within school subjects such as art, science, social science, civics, and health; that address the social construction of data; or that specify required evidence with associated metrics [4]. Frameworks for adapting AI guidelines to the K-12 educational context continue to be underdevelopment and require further research [9].

CONCLUSION

The growing influence of Artificial Intelligence in society highlights the urgent need for educational systems to develop learners who possess not only technical understanding of AI technologies but also the ability to critically evaluate their social, ethical, and civic implications. This study demonstrates that AI literacy and civic resilience are interconnected competencies that enable individuals to engage meaningfully in digital societies, make informed decisions, and participate responsibly in democratic processes. The analysis of curriculum models shows that

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inquiry-based, competency-based, interdisciplinary, and culturally responsive approaches provide valuable frameworks for developing comprehensive AI literacy. These models move beyond teaching AI concepts alone by encouraging learners to examine issues such as algorithmic bias, privacy, misinformation, fairness, and the societal consequences of automated systems. By integrating AI education across different disciplines and connecting learning to real-world contexts, educational institutions can strengthen students' ability to respond effectively to emerging technological challenges. Evaluation frameworks remain essential for ensuring the effectiveness and sustainability of AI literacy initiatives. Formative assessments support continuous improvement by capturing learner experiences and guiding curriculum refinement, while summative assessments measure the achievement of intended competencies and broader civic outcomes. However, evaluation processes must consider issues of equity, accessibility, cultural relevance, and the diverse contexts in which AI education is implemented. Successful implementation of AI literacy and civic resilience curricula requires strong policy support, well-prepared educators, adequate resources, and continuous adaptation to technological and societal changes. Existing initiatives demonstrate progress, but significant gaps remain, particularly in connecting AI education with civic engagement, social justice, and ethical responsibility. Future research should therefore focus on developing inclusive curriculum frameworks, evidence-based assessment tools, and adaptable models that address the needs of diverse learners. Ultimately, AI literacy should be understood as a foundation for responsible citizenship in the digital age. By combining technological knowledge with civic awareness, ethical reasoning, and critical engagement, education can prepare individuals and communities to shape AI development in ways that promote equity, democracy, and social resilience.

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CITE AS: Nyiramukama Diana Kashaka (2026). AI Literacy and Civic Resilience: Curriculum Models and Evaluation. NEWPORT INTERNATIONAL JOURNAL OF LAW, COMMUNICATION AND LANGUAGES, 6(2):1-8
<https://doi.org/10.59298/NIJLCL/2026/6.2.180000>