



WHITE PAPER

The Transformative Technology Literacy Framework (TTLF)

*A Competency-Based Framework for Developing,
Demonstrating, Assessing, and Recognizing Technology
Literacy in an AI-Driven World*

Prepared for Zengage Learning

Research • Education • Workforce Development • Lifelong Learning

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Executive Summary

Transformative technologies are reshaping how people learn, communicate, work, conduct research, develop businesses, and participate in the global economy. Artificial intelligence (AI), generative AI and large language models (LLMs), quantum computing, robotics, biotechnology, extended reality (XR), blockchain, cloud computing, and other emerging technologies are changing the knowledge and competencies required for academic achievement, career readiness, entrepreneurship, and lifelong learning.

Access to technology does not automatically produce technology literacy. A person may use digital tools regularly without possessing the vocabulary, conceptual understanding, communication skills, critical judgment, or demonstrated competencies necessary to explain technological concepts, evaluate information, solve problems, or apply knowledge in unfamiliar situations.

The Transformative Technology Literacy Framework (TTLF) addresses this challenge by providing a structured, competency-based approach to developing technology literacy as an integrated system of knowledge acquisition, comprehension, communication, practical application, assessment, validation, and recognition.

Developed within the educational mission of Zengage Learning, TTLF is intended to bridge the gap between understanding technology in theory and applying technology-related knowledge in academic, professional, entrepreneurial, and personal contexts.

The framework connects six dimensions of competency development:

- **Defined:** Establishing what technology literacy means and identifying the competencies to be developed.
- **Acquired:** Building foundational knowledge, vocabulary, comprehension, and understanding.
- **Demonstrated:** Showing that knowledge can be communicated, explained, and applied.
- **Assessed:** Evaluating competency through structured methods and evidence.

- **Validated:** Establishing the credibility, relevance, and reliability of demonstrated learning.
- **Recognized:** Communicating verified competencies in ways that support academic, professional, and career opportunities.

These six dimensions are supported by six core competencies: Reading, Listening, Writing, Speaking, Technology Fluency, and Articulation.

Together, these dimensions and competencies provide a model for moving beyond simple exposure to technology toward meaningful, demonstrable, and potentially recognizable technology literacy. TTLF also provides a conceptual foundation for Zengage Learning's broader Transformative Technology Literacy ecosystem, including the Transformative Technology Literacy Microlearning Series (TTLMS), the [Transformative Technology Literacy Microlearning Library \(TTLML\)](#), and associated educational, assessment, professional development, and partnership initiatives.

The central proposition of this white paper is that technology literacy should be treated as a structured, developable, demonstrable, and assessable set of competencies—not merely as familiarity with devices, software, or individual technology products.

1. Introduction: The Need for Transformative Technology Literacy

1.1 The changing nature of literacy

Traditional definitions of literacy emphasize the ability to read, write, interpret, and communicate information. Digital literacy expanded these expectations by incorporating the ability to use digital devices, software, online information, and networked communication tools. The emergence of transformative technologies requires a broader approach.

Today's learners increasingly encounter technologies that influence decisions, generate content, automate tasks, transform industries, and create new academic and career pathways. Understanding these technologies requires more than knowing how to operate an application.

A technology-literate individual should ideally be able to:

- Read and interpret explanations of unfamiliar technologies.
- Understand technical vocabulary and distinguish related concepts.
- Listen to explanations and identify key ideas, assumptions, and implications.
- Write clearly about technological concepts and their applications.
- Speak knowledgeably about technologies in academic or professional settings.
- Explain how technologies function, where they may be useful, and what limitations they present.
- Evaluate claims, recognize uncertainty, and identify potential risks.
- Apply knowledge to unfamiliar problems and changing circumstances.

These capabilities are especially important when technologies evolve faster than formal curricula, organizational policies, and conventional training programs can be revised.

1.2 The technology literacy gap

The technology literacy gap is the difference between the technological knowledge and competencies people possess and those they need to participate effectively in an increasingly technology-dependent society.

This gap can affect students preparing for college and future employment; adults seeking career transitions or advancement; individuals without college degrees or conventional professional experience; educators integrating emerging technologies into instruction; professionals seeking to remain relevant; entrepreneurs evaluating technologies; and employers seeking credible evidence of employee competencies.

The gap is not exclusively a hardware or internet-access problem. It is also a knowledge, comprehension, communication, assessment, and recognition problem. A learner may have access to sophisticated AI tools but lack the foundational understanding required to evaluate their output. Another learner may understand a technological concept but lack the vocabulary or communication skills to demonstrate that knowledge during a job interview.

TTLF addresses these challenges by connecting technology knowledge with the competencies needed to comprehend, communicate, apply, demonstrate, and document that knowledge.

1.3 The purpose of TTLF

The purpose of TTLF is to establish an adaptable framework for developing transformative technology literacy across educational and professional contexts.

1. Define technology literacy through identifiable competencies.
2. Establish a structured progression from knowledge acquisition to recognition.
3. Integrate communication and comprehension with technological understanding.
4. Support self-directed, competency-based, and lifelong learning.
5. Provide a foundation for assessment and evidence-based competency demonstrations.
6. Help learners connect technology knowledge to academic, career, and entrepreneurial opportunities.
7. Enable educators and organizations to adapt learning objectives as technologies evolve.
8. Support the documentation and recognition of learning acquired through formal education, independent study, workplace experience, and other learning environments.

TTLF is intended to be adaptable rather than tied to a particular device, software platform, educational institution, or technology vendor.

2. Conceptual Foundations of TTLF

2.1 Technology literacy as a combination of knowledge and performance

TTLF treats technology literacy as a multidimensional competency rather than a single technical skill. It recognizes that meaningful literacy involves knowing about a technology, understanding information about it, communicating that understanding, applying knowledge appropriately, and producing evidence of competency.

Capability	Description
Knowledge	Understanding foundational concepts, terminology, principles, applications, and limitations.
Comprehension	Interpreting explanations, connecting concepts, distinguishing related ideas, and evaluating claims.
Communication	Reading, listening, writing, and speaking about technology with clarity and appropriate terminology.
Application	Using technology-related knowledge to interpret situations, solve problems, make decisions, and pursue opportunities.
Evidence	Demonstrating and documenting learning through assessments, explanations, projects, practical work, or portfolios.

These capabilities are interdependent. Knowledge without comprehension may produce superficial familiarity. Comprehension without communication can make expertise difficult to demonstrate. Communication without accurate knowledge can create an impression of competence without substantive understanding. Evidence-based assessment helps distinguish these outcomes.

2.2 Why the framework is transformative

The term transformative emphasizes the potential of technology literacy to change how people learn, work, solve problems, and create opportunities. TTLF extends beyond the immediate operation of a particular technology. It encourages learners to develop conceptual foundations that can be transferred across tools, platforms, occupations, and emerging technology categories.

For example, a learner who understands the foundational concepts of machine learning may be better prepared to understand new AI applications than someone whose knowledge is limited to a single software interface. A learner who can interpret technical explanations, ask informed questions, evaluate evidence, and articulate trade-offs can continue learning as technologies evolve.

TTLF therefore emphasizes transferable understanding and adaptive learning alongside technology-specific knowledge.

2.3 A framework for different levels of prior experience

TTLF is intended to support beginners and experienced practitioners alike. For beginners, it provides a structure for acquiring vocabulary, understanding foundational concepts, and building confidence in communicating about unfamiliar technologies. For experienced learners, it provides a way to identify gaps, organize existing knowledge, demonstrate advanced understanding, and connect learning to new domains.

For educators and organizations, it provides a structure for defining expected competencies, designing learning experiences, evaluating performance, and documenting outcomes. The framework does not require learners to follow identical pathways. Learning activities, technology topics, assessment methods, and performance expectations can be adapted to the learner's context.



3. The Six Dimensions of TTLF

The six dimensions form the central organizing structure of the framework. They describe the progression from defining the desired competencies to establishing their assessment, validation, and recognition. They should be understood as connected dimensions rather than an inflexible, strictly linear sequence. Learners may revisit earlier dimensions, develop several competencies simultaneously, or demonstrate different levels of proficiency across technology subjects.

Dimension	Purpose	Typical evidence
Defined	Specify the knowledge and competencies expected.	Competency descriptions and criteria.
Acquired	Develop foundational knowledge and understanding.	Learning activities and knowledge checks.
Demonstrated	Show the ability to explain and apply learning.	Responses, presentations, tasks, or projects.
Assessed	Evaluate performance against explicit criteria.	Scores, rubrics, and performance evaluations.
Validated	Review the credibility and sufficiency of evidence.	Review records and verified evidence.
Recognized	Communicate verified achievements and competencies.	Certificates, badges, transcripts, or portfolios.

3.1 Dimension One: Defined

Purpose: Establish a clear description of the technology literacy competencies to be developed and the evidence that will indicate successful learning. Without clearly defined competencies, learners may not know what they are expected to understand, educators may have difficulty aligning instruction with outcomes, and assessors may apply inconsistent standards.

Key activities include identifying the technology subject or domain; establishing relevant terminology and foundational concepts; defining knowledge and comprehension expectations; identifying communication and application skills; setting learning objectives and performance expectations; establishing assessment criteria and acceptable evidence; and identifying contexts in which competencies will be useful.

For example, a course on Generative AI and LLMs might define competencies involving the distinction between generative AI and other forms of AI, the basic operation of large language models, prompt formulation, common applications, limitations, and responsible use.

Expected outcome: A defined competency profile that guides learning activities, assessment, and subsequent recognition.

3.2 Dimension Two: Acquired

Purpose: Develop the foundational knowledge, vocabulary, comprehension, and conceptual understanding required to meet the defined competencies. Knowledge acquisition may occur through formal education, independent study, microlearning, professional experience, reading, multimedia instruction, tutorials, demonstrations, and other learning activities.

Acquisition should not be equated with merely encountering information. Learning experiences should help learners develop meaningful relationships among concepts and understand how terminology relates to actual technologies and applications.

Key activities include reading technology explanations and reference materials; listening to lectures, discussions, interviews, and demonstrations; learning and reviewing domain-specific vocabulary; comparing related concepts; examining examples and use cases; asking questions; revisiting concepts from different perspectives; and connecting new knowledge with prior knowledge.

Expected outcome: A foundational body of knowledge that the learner can comprehend, explain, retain, and build upon.

3.3 Dimension Three: Demonstrated

Purpose: Establish that acquired knowledge can be communicated, explained, interpreted, or applied rather than simply recalled. Demonstration provides an opportunity for learners to make their understanding observable.

Possible demonstrations include explaining a technology in the learner's own words; writing a concise technical overview; comparing two technologies or applications; answering questions about terminology and principles; analyzing a case study; presenting a use case to a nontechnical audience; completing a practical task or simulation; and creating a project, report, or competency portfolio.

Demonstration should be appropriate to the defined learning objectives. A conceptual competency may be demonstrated through a well-supported explanation, while a practical competency may require a task or performance.

Expected outcome: Observable evidence that the learner can express or apply knowledge relevant to the stated competency.

3.4 Dimension Four: Assessed

Purpose: Evaluate demonstrated learning against established criteria.

Assessment determines the extent to which a learner has achieved expected competencies and should be aligned with the Defined dimension.

Assessment methods may include knowledge checks and quizzes; vocabulary assessments; reading and listening comprehension tasks; written explanations and short-answer questions; oral presentations and interviews; technology comparison exercises; scenario-based problem-solving; practical demonstrations; projects and case studies; and digital portfolios.

A sound assessment process should specify the competency being measured, the evidence required, the scoring criteria, and the standard for satisfactory performance. Where appropriate, assessment may distinguish recall, comprehension, application, analysis, and communication.

Assessment quality depends on alignment, fairness, accessibility, transparency, and the reliability of the evidence. An assessment of conceptual understanding should not inadvertently measure writing fluency alone unless writing is itself part of the competency.

Expected outcome: An evidence-based determination of the learner's demonstrated proficiency against specified criteria.

3.5 Dimension Five: Validated

Purpose: Establish that assessment results and supporting evidence are sufficiently credible, relevant, and trustworthy for their intended use. Assessment evaluates performance against criteria; validation examines whether the competency claim is adequately supported and whether the assessment and evidence are appropriate for the intended decision.

Validation may involve reviewing alignment between objectives and tasks; checking the accuracy and relevance of evidence; confirming consistent scoring; reviewing portfolio artifacts and demonstrations; verifying authenticity where necessary; establishing assessor qualifications or review procedures; evaluating whether an assessment measures the intended competency; and confirming that certificates accurately describe what was assessed.

In AI-supported learning environments, validation may consider the role of generative AI in producing written answers, reports, code, or other artifacts. Policies should distinguish permitted assistance from evidence that must reflect the learner's own knowledge or performance.

Validation procedures should be proportionate to the intended use. An introductory learning certificate and a professional qualification used for safety-critical work should not be treated as equivalent forms of evidence.

Expected outcome: A defensible basis for determining whether a demonstrated competency can be relied upon for its stated purpose.

3.6 Dimension Six: Recognized

Purpose: Make validated learning and competency achievements visible, interpretable, and useful to learners and relevant stakeholders. Recognition connects learning outcomes to potential opportunities in education, employment, professional development, entrepreneurship, and lifelong learning.

Possible forms of recognition include certificates of completion; certificates documenting assessed competencies; digital badges with clearly defined criteria; competency transcripts; learning records; digital portfolios; PLAR submissions; employer competency profiles; and evidence supporting academic admission or credit consideration.

Recognition should communicate what a learner has actually achieved. A certificate for completing a course should not automatically imply that the learner has passed a rigorous competency assessment. A verified competency record may support an application, but does not automatically guarantee employment, admission, academic credit, or professional licensure.

Expected outcome: A clear and credible record of learning or competency that can be presented for relevant academic or professional consideration.

3.7 How the six dimensions work together

The dimensions establish a logical connection between learning objectives, learning experiences, performance, evaluation, credibility, and recognition. Learning becomes more purposeful when competencies are defined in advance, assessment becomes more meaningful when it measures those competencies, and recognition becomes more credible when it rests on adequate evidence.



4. The Six Core Competencies of TTLF

The six dimensions describe how technology literacy can be developed and recognized. The six core competencies identify the capabilities learners develop and demonstrate through that process: Reading, Listening, Writing, Speaking, Technology Fluency, and Articulation. They are designed to work together rather than function as isolated skills.

4.1 Reading

Definition: The ability to read, interpret, comprehend, and critically evaluate written information about transformative technologies.

Reading encompasses more than recognizing words or locating definitions. It includes understanding relationships among concepts, interpreting specialized vocabulary, distinguishing central ideas from supporting details, and identifying implications.

Relevant capabilities include:

- Recognize and interpret technology terminology.
- Understand definitions, descriptions, and technical explanations.
- Identify main ideas and supporting evidence.
- Compare explanations and technology approaches.
- Interpret diagrams, tables, specifications, and technical examples.
- Identify assumptions, limitations, and uncertainty.
- Read critically when evaluating technology claims.
- Extract relevant information for practical application.

Example: A learner reads about edge AI and explains how processing data locally differs from sending data to a remote cloud service, including implications for latency, connectivity, privacy, and resource constraints.

Evidence of competency: Accurate comprehension responses, annotated materials, summaries, concept comparisons, and evidence-based explanations.

4.2 Listening

Definition: The ability to understand, interpret, evaluate, and retain spoken information about transformative technologies.

Listening helps learners process spoken explanations, recognize important details, distinguish evidence from opinion, and formulate relevant questions.

Relevant capabilities include:

- Identify key ideas in spoken explanations.
- Understand unfamiliar technical terms from context.
- Follow multistep explanations of technology processes.
- Distinguish main points from secondary information.
- Recognize differences between fact, interpretation, and speculation.
- Ask clarifying questions.
- Summarize and paraphrase spoken information.
- Compare information from different speakers.
- Listen effectively to technical and nontechnical audiences.

Example: After listening to a discussion about autonomous robotics, a learner summarizes the system's function, identifies the role of sensors and control systems, and explains safety concerns raised by the speakers.

Evidence of competency: Listening-comprehension assessments, accurate summaries, structured notes, responses to oral questions, and participation in technology discussions.

4.3 Writing

Definition: The ability to communicate technology-related knowledge and reasoning through clear, accurate, organized, and audience-appropriate written communication.

Writing makes knowledge visible and creates a record that can be reviewed, assessed, shared, and incorporated into a professional portfolio. It requires learners to organize concepts, select appropriate terminology, establish relationships, and communicate conclusions coherently.

Relevant capabilities include:

- Define and explain technological concepts.
- Write accurate summaries and descriptions.
- Compare technologies, applications, and use cases.
- Explain technical processes in accessible language.
- Develop reports, essays, and case-study analyses.
- Support claims with relevant evidence.
- Describe benefits, limitations, and risks.
- Adapt writing to technical and nontechnical audiences.
- Document sources and distinguish evidence from interpretation.

Example: A learner writes a brief report comparing generative AI and conventional rule-based software, explaining their different operating approaches, applications, and limitations.

Evidence of competency: Written explanations, reports, case studies, technical summaries, project documentation, and portfolio artifacts.

4.4 Speaking

Definition: The ability to communicate technology-related knowledge orally in a clear, coherent, accurate, and contextually appropriate manner.

Speaking competency is important in interviews, meetings, presentations, professional collaboration, teaching, consulting, and entrepreneurship.

Relevant capabilities include:

- Explain technology concepts in one's own words.
- Present information in a logical sequence.
- Use technical vocabulary appropriately.
- Respond accurately to questions.
- Explain complex concepts to beginners.
- Participate in technical discussions.
- Compare solutions and justify recommendations.
- Acknowledge uncertainty and knowledge limitations.
- Deliver structured presentations and demonstrations.

Example: During a job interview, a candidate explains how retrieval-augmented generation can help an AI application use information retrieved from external sources and why retrieval quality and source relevance matter.

Evidence of competency: Oral examinations, interviews, recorded presentations, demonstrations, discussions, and scenario-based responses.

4.5 Technology Fluency

Definition: The ability to understand, navigate, evaluate, and apply technology-related knowledge and tools appropriately in relevant contexts.

Technology fluency extends beyond operational familiarity. It involves understanding enough about a technology to identify its purpose, recognize capabilities and limitations, evaluate applications, and make informed decisions. Fluency is context-dependent.

Relevant capabilities include:

- Understand foundational principles and terminology.
- Identify common applications and use cases.
- Recognize relationships among technologies.
- Understand basic system components and processes.
- Select appropriate tools for particular tasks.
- Recognize limitations, risks, and dependencies.
- Evaluate information generated by technological systems.
- Apply knowledge to unfamiliar scenarios.
- Transfer prior understanding to new tools.
- Consider ethical, privacy, security, and accessibility issues.

Example: A learner evaluates whether a cloud-based AI service or an edge-based AI implementation is more appropriate for a particular application, considering connectivity, latency, cost, data sensitivity, and maintenance.

Evidence of competency: Scenario analyses, technology-selection exercises, practical demonstrations, structured comparisons, and applied projects.

4.6 Articulation

Definition: The ability to express and connect technology-related knowledge in a precise, coherent, meaningful, and audience-appropriate way.

Articulation overlaps with writing and speaking but emphasizes the quality of the explanation itself: whether the learner can express what they understand, connect concepts, explain why relationships matter, and make the significance clear.

Relevant capabilities include:

- Explain concepts in one's own words.
- Define terms precisely and in context.
- Connect foundational principles to applications.
- Distinguish similar or easily confused concepts.
- Explain cause-and-effect relationships.
- Translate technical language into accessible explanations.

- Support conclusions with relevant reasoning.
- Answer follow-up questions coherently.
- Identify gaps in one's own understanding.
- Explain technology's significance to a problem or audience.

Example: A learner explains the relationships among AI models, training data, inference, prompts, and generated outputs without suggesting that every AI system operates identically.

Evidence of competency: Concept explanations, oral defenses, structured written responses, concept maps, technical briefings, and probing-question responses.

4.7 How the six competencies reinforce one another

Competency	Primary contribution
Reading	Accesses and interprets written knowledge.
Listening	Accesses and interprets spoken knowledge.
Writing	Organizes and records understanding.
Speaking	Communicates understanding orally.
Technology Fluency	Connects knowledge with informed application.
Articulation	Makes understanding precise, connected, and explainable.

Consider a learner studying blockchain technology. The learner reads about distributed ledgers, listens to an explanation of consensus mechanisms, writes a comparison of blockchain applications, speaks about a use case, evaluates when blockchain may be appropriate, and articulates the relationships among decentralization, consensus, and transaction verification. Together, these activities provide a more complete picture of understanding than a single vocabulary test.

The six competencies do not require equal proficiency in every situation. The appropriate combination depends on the defined learning outcomes.

5. The Relationship Between TTLF, Curriculum, and Instruction

5.1 Competency-based curriculum design

A curriculum informed by TTLF begins by identifying what learners should know and be able to demonstrate. Curriculum developers can:

1. Identify the technology domain and its foundational concepts.
2. Define required vocabulary and comprehension outcomes.
3. Map learning objectives to the six core competencies.
4. Select learning resources and instructional activities.
5. Establish opportunities to practice explaining and applying knowledge.
6. Develop assessment criteria and evidence requirements.
7. Determine how validated outcomes may be documented or recognized.
8. Review and revise the curriculum as technology and practice evolve.

This approach allows learning objectives to remain stable where foundational principles remain relevant while examples, tools, and applications are updated.

5.2 The role of microlearning

Microlearning can support TTLF by organizing complex subject areas into manageable, focused learning experiences. The Transformative Technology Literacy Microlearning Series (TTLMS) is positioned to operationalize this approach through its technology-focused courses and associated resources.

A TTLMS course can introduce core terminology, explain foundational concepts, present applications, and provide questions or assessments that reinforce comprehension. Supplemental materials can extend the experience through tutorials, articles, videos, eBooks, audiobooks, keyword glossaries, study guides, quizzes, and other resources.

Microlearning is a delivery approach, whereas TTLF is the broader competency framework. Microlearning supports acquisition, but additional activities and assessments may be necessary to demonstrate, assess, validate, and recognize proficiency.

5.3 Repetition and learning retention

Technology literacy requires repeated exposure to important terminology and concepts. Learners may encounter a term in a definition, revisit it in an explanation, hear it in a video, apply it in a scenario, and use it in a written or oral response.

A TTLF-aligned sequence may include initial exposure to terminology; a plain-language explanation; a contextual example; a comprehension question; comparison with a related concept; practical application; later review or retrieval; and a final demonstration of understanding.

Repeated exposure should not be reduced to repetition alone. The goal is to help learners recall, comprehend, connect, and use knowledge rather than merely recognize familiar words.

5.4 Instructional flexibility

TTLF can accommodate instructor-led, self-directed, online, blended, workplace, and project-based learning. Educators may use the framework to establish outcomes, facilitate discussions, design activities, assess work, and guide portfolio development. Independent learners can use it to structure study and identify competency gaps. The framework can also support interdisciplinary instruction by providing a common structure for teaching and assessing technology literacy across subjects.

6. Assessment, Validation, and Evidence of Competency

A central principle of TTLF is that learning outcomes should be connected to evidence appropriate to the competency being claimed. Attendance, study time, or course completion may indicate participation, but these indicators alone do not establish the full extent of understanding or ability.

6.1 A tiered assessment model

Level	Focus	Illustrative evidence
Level 1	Foundational knowledge	Identify terms, definitions, components, and basic principles.
Level 2	Comprehension	Explain concepts, summarize information, and distinguish related ideas.
Level 3	Application	Apply knowledge to examples, scenarios, and practical questions.
Level 4	Analysis and evaluation	Compare alternatives, evaluate claims, and identify limitations or risks.
Level 5	Integrated demonstration	Combine knowledge, communication, and application in a project, presentation, or portfolio.

These levels are a proposed operational approach for implementing TTLF, not a requirement that every course use five levels or that all competencies follow a universal progression.

6.2 Standardized rubrics

Rubrics can make assessment more consistent by defining performance criteria and describing what different levels of proficiency look like. A TTLF-aligned rubric might evaluate:

- Accuracy of terminology.

- Depth of conceptual understanding.
- Comprehension of relevant information.
- Quality of reasoning and supporting evidence.
- Appropriateness of technology application.
- Clarity of written or oral communication.
- Ability to identify limitations and uncertainty.
- Independence and authenticity of demonstrated performance, where relevant.

Rubrics should be adapted to the intended competency. An introductory technology overview should not be evaluated using the same technical standards as an advanced engineering project.

6.3 Digital portfolios and prior learning

A digital portfolio can bring together written explanations, assessments, project reports, demonstrations, presentations, and documented work experience. For learners pursuing academic or career opportunities, a portfolio can help communicate knowledge that is not adequately represented by a traditional resume or list of course completions.

A PLAR portfolio might include:

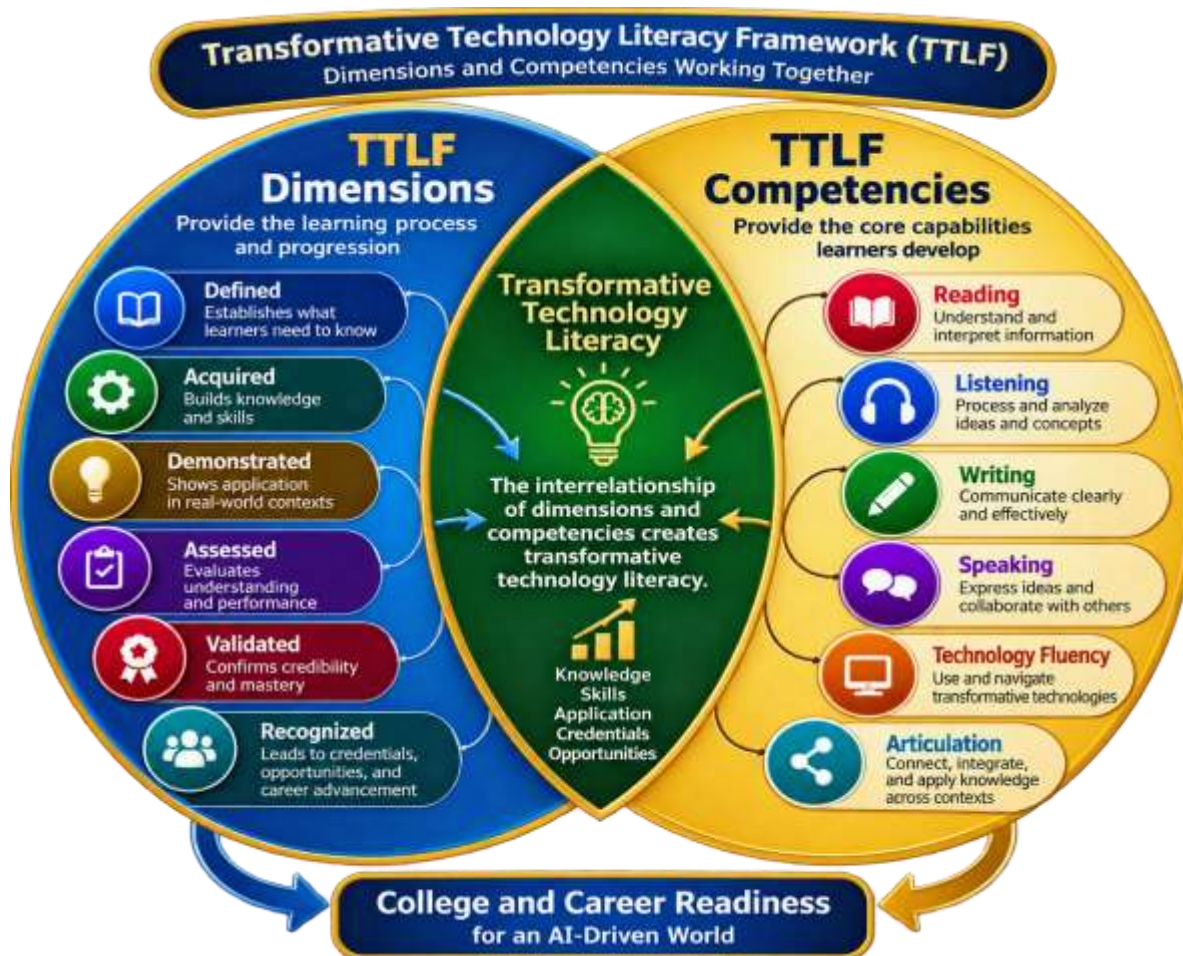
9. A competency statement describing the learner's claim.
10. Relevant learning or professional experience.
11. Supporting artifacts or work samples.
12. Written explanations connecting evidence to the competency.
13. Assessment results or demonstrations, where required.
14. Reflection on knowledge gaps and further learning.
15. Verification or assessor review, as appropriate.

The framework does not itself confer academic credit or professional qualifications. Institutions and employers determine whether submitted evidence meets their own standards.

6.4 Responsible use of artificial intelligence in assessment

AI tools can assist with feedback, practice questions, formative assessment, and learning support. However, AI-generated evaluation should not automatically be treated as conclusive evidence of competency. A responsible approach should consider accuracy and consistency; privacy; bias and accessibility; transparency about permitted assistance; human review of consequential decisions; methods for confirming learner understanding; and attribution and academic-integrity policies.

TTLF can incorporate these concerns into competency definitions, instructional activities, assessment procedures, and validation standards.



7. TTLF and Established Digital Competency Frameworks

TTLF can be understood in relation to existing frameworks that address digital capabilities, technology integration, and educational practice. Relevant references include UNESCO's ICT Competency Framework for Teachers, Jisc's Building Digital Capabilities framework, the ISTE Standards, and the NAEP Technology and Engineering Literacy Framework. These frameworks address related but distinct needs. TTLF should be positioned as complementary rather than as a replacement.

Framework	Primary orientation	Relationship to TTLF
TTLF	Integrated technology literacy, communication, comprehension, competency assessment, validation, and recognition.	Organizing model for the Zengage Learning technology literacy ecosystem.
UNESCO ICT CFT	Educator competencies for integrating ICT into teaching, curriculum, assessment, administration, and professional development.	Reference for educator preparation and instructional integration.
Jisc Digital Capabilities	Digital proficiency, information and media literacy, communication, digital creation, learning, and digital identity.	Complementary perspective on capabilities needed in digital society.
ISTE Standards	Technology-related expectations for learners, educators, leaders, and other educational stakeholders.	Supports educational goals and technology-enabled practice.

NAEP Technology and Engineering Literacy	Assessment of students' understanding and use of technology and engineering in problem-solving contexts.	Reference for defining assessable technology and engineering outcomes.

UNESCO describes its ICT Competency Framework for Teachers as a resource for teacher preparation, curriculum development, professional learning, and technology-related education policy. Jisc organizes digital capabilities into six elements, including information literacy, digital communication, problem-solving, learning, and digital identity.

The conceptual distinction of TTLF is its integration of six communication and technology competencies with a six-dimensional process for developing and recognizing technology literacy. This is a conceptual distinction, not evidence that TTLF is inherently superior. Comparative claims about effectiveness, assessment reliability, or employment outcomes require empirical investigation.

7.1 Potential integration with TPACK and SAMR

TPACK (Technological Pedagogical Content Knowledge) focuses on the intersecting knowledge teachers need to integrate technology with pedagogy and subject matter. TTLF can complement TPACK by helping educators define the technology literacy competencies learners should develop and demonstrate.

SAMR (Substitution, Augmentation, Modification, Redefinition) is a model for examining how technology is used to support or transform learning tasks. TTLF can complement SAMR by focusing on what learners understand and can demonstrate when technology-enabled activities are used.

- TPACK helps educators think about the knowledge required to integrate technology into teaching.
- SAMR helps educators reflect on how technology changes learning tasks.
- TTLF helps educators define, develop, assess, and document technology literacy competencies.

The models address different questions and can be used together where their purposes align.

8. Technology Literacy Across Emerging Technology Domains

TTLF is designed to accommodate a wide range of technology categories. Its competencies can be applied to established digital systems as well as emerging and rapidly evolving fields. The framework does not require every learner to master every domain; it provides a common structure for foundational literacy and deeper competencies in selected subjects.

8.1 Artificial intelligence, data, and intelligent software

Relevant topics include: Artificial intelligence and machine learning; generative AI and large language models; AI agents and copilots; artificial general intelligence as a research concept; big data and advanced analytics; AI governance, safety, and trust; and intelligent software applications.

Potential literacy outcome: Learners may explain core AI concepts, distinguish related terminology, assess the reliability of generated information, and identify appropriate applications.

8.2 Advanced computing and digital infrastructure

Relevant topics include: Quantum computing; cloud computing and infrastructure; edge AI and edge computing; Internet of Things (IoT); fifth- and sixth-generation networks (5G and 6G); cybersecurity and digital identity; and satellite mega-constellations.

Potential literacy outcome: Outcomes may include understanding system architecture at an appropriate level and evaluating trade-offs involving connectivity, latency, security, cost, and scalability.

8.3 Robotics and autonomous systems

Relevant topics include: Industrial and service robotics; autonomous vehicles and systems; sensors and control systems; human-robot interaction; autonomous navigation; and robotic process automation.

Potential literacy outcome: Learners may explain how sensing, control, software, and physical systems work together and recognize limitations and safety implications.

8.4 Biotechnology and engineering biology

Relevant topics include: Biotechnology; genetic engineering and CRISPR; synthetic biology; bioinformatics; brain-computer interfaces; and laboratory automation.

Potential literacy outcome: Literacy should emphasize foundational concepts, applications, evidence quality, safety, ethical questions, and limits of expertise.

8.5 Extended reality and spatial intelligence

Relevant topics include: Virtual reality (VR); augmented reality (AR); mixed reality (MR); spatial computing; digital twins; and three-dimensional modeling and simulation.

Potential literacy outcome: Learners may examine how immersive systems represent environments, support training, visualize information, and connect digital representations with physical systems.

8.6 Energy and clean technology

Relevant topics include: Renewable energy systems; energy storage; smart grids; advanced batteries; electrification; carbon measurement and management; and emerging clean-energy technologies.

Potential literacy outcome: Competencies include interpreting system concepts, comparing applications, and evaluating evidence about performance, cost, environmental impact, and limitations.

8.7 Blockchain and decentralized technologies

Relevant topics include: Distributed ledgers; cryptographic foundations; consensus mechanisms; smart contracts; tokenization; decentralized applications; and digital asset infrastructure.

Potential literacy outcome: Learners should explain underlying concepts, distinguish technical capabilities from marketing claims, recognize security and governance risks, and evaluate appropriate uses.

8.8 An adaptable subject architecture

For each technology domain, a TTLF-aligned curriculum can identify core terminology and concepts; foundational knowledge requirements; reading and listening resources; writing, speaking, and articulation activities; technology fluency outcomes; assessments and demonstrations; validation requirements where applicable; and recognition options. This structure supports curricular expansion without requiring a new overarching literacy model for every emerging technology.

9. Implementation Within the Zengage Learning System

The Transformative Technology Literacy Framework provides the conceptual foundation for the Zengage Learning System (ZLS), connecting learning resources, competency development, assessment, and potential educational and professional opportunities. Zengage Learning, an educational publisher, can use TTLF to align its learning programs and supporting resources around a consistent approach to technology literacy.

9.1 The relationship between TTLF and TTLMS

The Transformative Technology Literacy Microlearning Series (TTLMS) provides a practical pathway for introducing learners to a broad range of transformative technology subjects. Its 40 micro courses can support the Acquired dimension by developing foundational knowledge and terminology. Associated questions, quizzes, projects, and other learning activities can help learners progress toward Demonstrated and Assessed outcomes.

A complete implementation should distinguish course completion from demonstrated proficiency and validated competency.

TTLF dimension	Potential TTLMS implementation
Defined	Clearly stated course objectives and competency expectations.
Acquired	Micro courses, eBooks, tutorials, articles, videos, and keyword glossaries.
Demonstrated	Written explanations, questions, presentations, projects, and practical activities.
Assessed	Quizzes, comprehension questions, structured assessments, and rubrics.
Validated	Appropriate review of assessment results, portfolios, and competency evidence.
Recognized	Certificates, competency records, and portfolio documentation aligned with achievement.



9.2 The role of TTLML

The [Transformative Technology Literacy Microlearning Library \(TTLML\)](#) can support continuing development by making supplementary resources available across technology subjects. Its articles, tutorials, courses, videos, eBooks, audiobooks, keyword glossaries, assessments, and other resources can support different learning preferences and provide opportunities for review.

A learner may complete an introductory course, consult a glossary to strengthen vocabulary, read additional articles to deepen understanding, take a practice quiz, and prepare a portfolio artifact demonstrating the ability to explain a concept. This creates a flexible learning environment in which users can revisit concepts and pursue further study as needs change.

9.3 The role of the Cox Institute

The Cox Institute of Transformative Technology Literacy (CITTL) can provide a focal point for research, thought leadership, framework development, and evaluation. Potential areas of work include:

- Refining operational definitions of TTLF competencies.
- Developing standardized competency descriptions and assessment rubrics.
- Researching effective approaches to technology literacy education.
- Evaluating the reliability and validity of assessment methods.

- Investigating relationships between technology literacy, college readiness, and career readiness.
- Developing guidance for educators and organizational partners.
- Publishing research and implementation resources.
- Evaluating framework performance across populations and learning contexts.

Research activity would help establish which elements of TTLF are most effective for particular educational objectives and how implementation can be improved.

9.4 Independent learning and professional partnerships

TTLF can support a community of educators, independent professionals, and other partners who help extend technology literacy opportunities. Independent professionals may adapt learning activities, develop supplementary resources, provide subject-matter expertise, and support learners in rapidly changing technology domains.

Within a partnership program, TTLF can provide a shared language for describing intended competencies and aligning educational activities. Partnership participation should be distinguished from formal validation authority. Any partner authorized to assess or certify competency should operate under clearly defined criteria, quality controls, and appropriate oversight.

10. Applications in Education, Employment, and Lifelong Learning

10.1 College and career readiness

TTLF can help learners develop the vocabulary, comprehension, and communication competencies needed to engage with technology-related academic and career pathways. A learner exploring AI, for example, can build foundational knowledge before deciding whether to pursue a technical degree, a professional certificate, an entrepreneurial project, or another pathway. The framework also offers educators a way to connect introductory technology literacy with more advanced academic and occupational competencies.

10.2 Employment and career transitions

For job seekers, particularly those without conventional credentials or extensive professional experience, TTLF can help structure the process of learning about technologies and documenting that learning. A learner may develop a portfolio containing:

- A concise explanation of a technology.
- A comparison of related technologies.
- A case-study analysis.
- A project demonstrating an application.
- Assessment results.
- A presentation or oral explanation.
- A reflection identifying further learning needs.

These artifacts can help a candidate communicate technology-related knowledge during interviews and other professional evaluations. They do not substitute automatically for required work experience, professional licenses, or specialized technical skills. Rather, they provide additional evidence that employers can consider alongside other qualifications.

10.3 Prior Learning Assessment and Recognition

TTLF's structure can support PLAR by connecting previously acquired knowledge with explicit competency descriptions and evidence requirements. An individual may have acquired technology knowledge through self-directed learning, employment, entrepreneurship, community activities, or other experiences.

A TTLF-aligned process can help the individual identify relevant competencies, assemble supporting evidence, address gaps, and prepare a portfolio for review. Where an institution accepts PLAR, that evidence may contribute to decisions about admission, credit, advanced standing, or other recognition. The receiving institution retains responsibility for its own requirements and decisions.

10.4 Entrepreneurship and innovation

Entrepreneurs need to understand technologies that may affect their markets, products, services, and operations. TTLF can help structure the learning required to evaluate technological opportunities, understand relevant terminology, communicate with technical collaborators, and explain potential applications to customers or investors.

For example, an entrepreneur considering an AI-enabled service may need to understand the underlying technology, identify realistic use cases, evaluate data and privacy concerns, and articulate the value proposition to a nontechnical audience. The framework can support these capabilities without assuming that technology literacy alone guarantees entrepreneurial success.

10.5 Lifelong learning and adaptability

Because technology evolves continuously, technology literacy cannot be treated as a one-time achievement. TTLF can support a recurring process in which learners identify new knowledge requirements, acquire relevant information, demonstrate updated competencies, and document further development. This approach emphasizes the capacity to continue learning as technologies and professional expectations change.

11. Implementation Roadmap

Phase	Focus	Key activities
Phase 1: Define	Clarify the framework.	Finalize competency definitions, terminology, learning outcomes, and assessment principles.
Phase 2: Map	Align existing resources.	Map selected TTLMS courses and TTLML resources to the six dimensions and six competencies.

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Phase 3: Develop	Create implementation tools.	Develop learning activities, assessments, rubrics, demonstration tasks, and portfolio guidance.
Phase 4: Pilot	Test in practice.	Pilot with selected learners, educators, and professional partners.
Phase 5: Evaluate	Review evidence.	Examine learner performance, assessment consistency, accessibility, usability, and feedback.
Phase 6: Expand	Improve and scale.	Refine the framework, publish implementation guidance, and extend to additional technology domains.

11.1 Evaluation indicators

Zengage Learning and participating organizations could monitor indicators such as:

- Learner performance on foundational knowledge assessments.
- Reading and listening comprehension outcomes.
- Improvement in written explanations and oral presentations.
- Ability to apply knowledge to unfamiliar scenarios.
- Retention of essential terminology and concepts.
- Quality and completeness of learner portfolios.
- Consistency among assessors using shared rubrics.
- Accessibility and usability of learning resources.

- Learner engagement and course completion.
- Evidence of further educational or professional progression.

Evaluation should distinguish outputs from outcomes. The number of courses published, learners enrolled, or certificates issued measures activity, but does not independently establish framework effectiveness. Claims about improved employment, academic admission, earnings, or long-term outcomes should be evaluated using suitable research designs and relevant evidence.

12. Research Agenda and Future Development

TTLF offers a structured conceptual model, but its long-term credibility will depend on continued development, transparent documentation, and empirical evaluation. Several research priorities are important:

Competency definition and measurement. Determine whether the six core competencies are sufficiently distinct, whether they capture important dimensions of technology literacy, and how they should be measured across domains.

Assessment reliability and validity. Examine whether assessment tasks and rubrics produce consistent results and accurately represent the competencies being claimed.

Learning effectiveness. Evaluate whether TTLF-aligned instruction improves comprehension, retention, communication, and transfer of knowledge to new situations.

Accessibility and inclusion. Consider learners with different levels of prior education, digital access, language proficiency, disabilities, and learning needs.

Technology evolution. Distinguish enduring competencies from technology-specific knowledge that may become outdated, and establish review procedures for course content.

Workforce relevance. Work with employers and professional organizations to identify occupation-relevant competencies and appropriate interpretations of competency evidence.

Recognition and portability. Examine whether competency records are understandable and useful across educational institutions, employers, and professional contexts.

Responsible AI integration. Investigate appropriate ways to use AI while protecting learner agency, privacy, fairness, and the credibility of demonstrated competency.

These research priorities provide opportunities for the Cox Institute and its collaborators to strengthen TTLF over time.

13. Guiding Principles for TTLF Implementation

1. **Competency-centered learning:** Define what learners should know and be able to demonstrate rather than relying exclusively on time spent studying.
2. **Communication and comprehension:** Treat reading, listening, writing, speaking, and articulation as essential components of technology literacy.
3. **Technology fluency:** Connect foundational knowledge with informed application and critical evaluation.
4. **Adaptability:** Allow learning objectives and examples to evolve as technologies change.
5. **Evidence-based assessment:** Align assessments with explicit competencies and appropriate performance criteria.
6. **Credible recognition:** Ensure that certificates and competency records accurately represent what was learned and assessed.
7. **Accessibility and inclusion:** Design learning and assessment opportunities for diverse learners and contexts.
8. **Responsible technology use:** Incorporate appropriate attention to privacy, security, ethics, limitations, and human accountability.
9. **Transferability:** Encourage learners to apply foundational understanding across technologies and situations.
10. **Continuous improvement:** Use research, feedback, and assessment results to refine the framework and its implementation.

14. Conclusion

The Transformative Technology Literacy Framework provides a structured approach to understanding technology literacy as an integrated set of knowledge, comprehension, communication, application, assessment, and recognition capabilities.

Its six dimensions—Defined, Acquired, Demonstrated, Assessed, Validated, and Recognized—connect learning objectives with evidence of achievement. Its six core competencies—Reading, Listening, Writing, Speaking, Technology Fluency, and Articulation—identify the capabilities through which learners develop and communicate technology-related understanding.

Together, these elements offer a foundation for curriculum design, microlearning, self-directed study, competency assessment, digital portfolios, PLAR, professional development, and lifelong learning.

Within the Zengage Learning System, TTLF can provide a common structure connecting the Transformative Technology Literacy Microlearning Series, the [Transformative Technology Literacy Microlearning Library](#), research initiatives, educator resources, and professional partnerships.

Its potential contribution is to help learners move from encountering unfamiliar technologies to understanding them, communicating about them, applying relevant knowledge, and producing evidence of their competencies.

Realizing that potential will require careful implementation, transparent assessment standards, inclusive learning design, and continued research. With these elements in place, TTLF can serve as an adaptable foundation for developing technology literacy across educational, professional, and societal contexts.

The long-term vision is a learning ecosystem in which people can continue developing their understanding of transformative technologies, demonstrate what they know, and use that knowledge to pursue meaningful academic, career, and entrepreneurial opportunities.

References and Further Reading

The following established frameworks provide relevant background and points of comparison for TTLF. They are reference materials, not endorsements or formal validations of TTLF.

1. UNESCO. UNESCO ICT Competency Framework for Teachers, Version 3. (2018). <https://www.unesco.org/en/digital-competencies-skills/ict-cft>
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3. UNESCO. AI Competency Framework for Teachers. (2024). <https://www.unesco.org/en/articles/ai-competency-framework-teachers>
4. International Society for Technology in Education (ISTE). ISTE Standards. <https://iste.org/standards>
5. National Assessment Governing Board. Technology and Engineering Literacy assessment resources. <https://www.nagb.gov/>

Publication notes: This white paper presents a detailed conceptual and proposed implementation model for TTLF. Claims regarding the framework's effectiveness, comparative advantages, assessment validity, and impact on educational or employment outcomes should be supported by future empirical research.

