Redefining Collaboration: A Framework for Skill Development in K–12 Education

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Preface

This publication is part of a series focused on conceptualization and assessment of skills.

Abstract

Successful collaboration in civic life, the workplace, and educational contexts requires that students have opportunities to develop collaboration skills through early educational and extracurricular experiences. To support this goal, a collaboration framework must clearly define the construct, articulate its dimensions as distinct yet interconnected indicators of the subskill, and provide observable behavioral examples. Such a framework enables educators to guide instruction, support formative and summative assessment, and promote students' ongoing growth in developing collaboration skills. This paper draws on existing collaboration frameworks, state-adopted competency standards, and assessment practices to propose a theoretical framework for defining and identifying evidence of collaboration in K-12 education, with a specific focus on high school learners. The framework proposes three subskills, corresponding subskill indicators, and examples of behaviors across learning contexts. We further explore considerations for implementation, including alignment with curricular goals, equitable access to opportunities for skill demonstration, and other practical considerations for integration into classroom settings. This work provides a foundation for developing and assessing collaboration skills, by highlighting the complex and context-dependent nature of collaboration, discussing the importance of considering technology-enhanced assessments, and recognizing the need for culturally responsive adaptations to ensure relevance and fairness in assessing this critical skill.

Keywords: collaboration skills, assessment, competency-based education, Portrait of a Graduate

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Collaboration skills are essential for interpersonal activities across social, academic, and professional settings. In educational contexts, students who demonstrate strong collaboration skills are more likely to engage positively with peers, sustain productive relationships, and contribute to group-based learning activities in ways that foster cognitive, academic, and social development (Andrews & Rapp, 2015; L. Liu et al., 2016; Tolmie et al., 2010; Wentzel & Watkins, 2019). Collaboration is also highly valued in both virtual and in-person work environments (Morrison-Smith & Ruiz, 2020; Patel et al., 2012) and consistently ranks among the most in-demand durable skills across industries (Cole et al., 2021; Rios et al., 2020).

The nature of collaboration itself is evolving. As digital tools and AI increasingly mediate interpersonal interactions, traditional conceptions of collaboration skills may fall short. Studies examining AI-supported learning environments have found that students must develop new skills, such as critically evaluating AI-generated suggestions, understanding AI limitations and biases, and determining when to rely on or override AI recommendations (Holstein et al., 2023; Kasneci et al., 2023). In K-12 settings, this shift also entails supporting students in articulating reasoning about their choices for creating certain AI input and their decisions for interpreting and using AI outputs, developing metacognitive awareness of AI capabilities, and adapting their collaborative strategies based on the affordances and constraints of AI partners (Chakraburty et al., 2025; Ouyang & Jiao, 2024).

Collaboration skills also intersect with other durable skills, such as communication (Dowell et al., 2020; Owens & Hite, 2022) and critical thinking, especially in complex problem-solving contexts (Xu et al., 2023). Yet, few existing frameworks provide a developmental roadmap tailored to K-12 learners that spans multiple real-world contexts, including peer groupwork, synchronous and asynchronous online environments, and human-AI interactions. More generally, many frameworks do not address the educational realities of K-12 learners, especially the need to support instruction, advance classroom-based assessment, and increase opportunities to demonstrate skills.

To address these gaps, this paper introduces a collaboration skills framework designed to support the implementation and assessment of Portrait of a Graduate (PoG) competencies in K-12 education (Atwell & Tucker, 2024; Mills et al., 2024). We conceptualize collaboration as a set of skills, rather than a single behavior or innate ability, because students can cultivate their skills

through instruction, feedback, and experiences. Although we recognize that collaboration skills develop over the lifespan, we focus specifically on high school students. Learners in this demographic are still actively developing their social skills, so instructional interventions aimed at supporting collaboration skills are likely to have a positive impact on outcomes reflecting postsecondary success (Napolitano et al., 2021; Wentzel & Watkins, 2019), a key objective of PoG and postsecondary readiness initiatives. Furthermore, outlining specific behavioral examples of collaboration skills for this population may help establish an upper anchor for conceptualizing progressions across K-12 grade levels. In this way, the framework can also inform the design of instructional resources that reflect developmental coherence of collaboration skills across K-12 education.

With this focus in mind, the proposed framework refines the conceptualization of collaboration skills and breaks it down into subskills and subskill indicators, the latter of which can be linked to observable behaviors. This design allows educators to more systematically teach, assess, and monitor students' development of collaboration skills, thereby helping move PoG goals from aspirational visions to actionable, evidence-based practices. Ultimately, the proposed framework has implications for the design of collaboration skills assessments for K-12 learners and how these assessments are integrated into existing curricula in ways that capture the dynamic nature of collaboration, leverage technology, and support cross-cultural collaboration. Future work should seek to build on and improve this framework by gathering feedback from educators, curriculum designers, assessment developers, and policymakers.

Existing Collaboration Frameworks

Collaboration has received significant attention from organizations dedicated to equipping learners with the skills necessary for success in the modern workplace, as well as from researchers in education and organizational science focused on team dynamics. Numerous frameworks have defined collaboration, or related constructs such as collaborative problem solving or collaborative learning, including models developed by educational researchers (e.g., L. Liu et al., 2016; Sun et al., 2020), large-scale assessments administered by intergovernmental organizations (e.g., OECD, 2013), and career readiness initiatives developed by national and global organizations (e.g., Cole et al., 2021; Evans, 2020; Education Design Lab, n.d.; Partnership for 21st Century Skills, 2009; XQ, n.d.). Importantly, these frameworks and initiatives vary in how they operationalize and define collaboration skills. For example, the

OECD's Collaborative Problem Solving (CPS) framework (2013) operationalized collaboration through digital simulations that measured how individuals coordinate roles, build mutual understanding, and make joint decisions. L. Liu et al. (2016) similarly defined CPS subskills based on discourse patterns such as sharing, negotiating, regulating, and maintaining social interactions. Focusing on collaboration more generally, the Partnership for 21st Century Skills (2009) emphasizes shared responsibility, conflict resolution, and valuing diverse perspectives in collaboration, and the Education Design Lab's 21st Century Skills Framework (n.d.) defines collaboration as building relationships, listening with empathy, and coordinating actions to achieve shared outcomes. Evident from these examples, frameworks overlap in their conceptualization of collaboration skills, but also vary in the skills emphasized.

At the state level, PoG frameworks (see Atwell & Tucker, 2024) have increasingly prioritized collaboration as a core graduate competency. For example, Kentucky's Portrait of a Learner (Kentucky Department of Education, 2024) identifies collaboration skills, such as working together to reach desired goals, recognizing the contributions of group members, giving and receiving feedback, and engaging with diverse perspectives. Utah's Competency-Based Learning Framework (Utah State Board of Education, 2021) also positions collaboration as essential for supporting team efforts, effectively applying tools and resources, valuing individual contributions, and connecting multiple perspectives. Similarly, North Carolina's Portrait of a Graduate (North Carolina Department of Public Instruction, n.d.) includes collaboration as a key skillset that encompasses working effectively with group members to achieve desired goals, resolving conflict, interacting with others respectively in-person and online, and serving as a group participant and leader. These frameworks treat collaboration as a multifaceted capacity that can be cultivated through intentional instructional design and scaffolded interactions. However, these frameworks vary in how they define collaboration skills, leading to differences in terminology, subskill emphasis, and intended learning outcomes.

Across the reviewed frameworks (see Table S1 in Supplemental Materials), several core subskills consistently appear as essential to effective collaboration, including:

1. Communicating with group members in a manner that is open, inclusive, and respectful (see Binkley et al., 2012; Evans, 2020; Griffiths et al., 2021; North Carolina Department of Public Instruction, n.d.; Pearson, 2022; Sun et al., 2020);

2. Participating actively through the sharing of ideas and resources (see EBSCO Connect, 2026; Evans, 2020; Griffiths et al., 2021; L. Liu et al., 2016; OECD, 2013);
3. Organizing, reflecting, and managing progress toward group goals (see Evans, 2020; Kentucky Department of Education, 2024; L. Liu et al., 2016; Pearson, 2022; Sun et al., 2020; Zhuang et al., 2008);
4. Negotiating, compromising, and resolving conflicts within groups (e.g., Evans, 2020; L. Liu et al., 2016; Partnership for 21st Century Skills, 2009; North Carolina Department of Public Instruction, n.d.; Pearson, 2022; XQ, n.d.); and
5. Working constructively with individuals from diverse backgrounds and perspectives (e.g., EBSCO Connect, 2026; Muller, 2021; North Carolina Department of Public Instruction, n.d.; Partnership for 21st Century Skills, 2009; XQ, n.d.).

While there is notable overlap across frameworks, they differ in emphasis, structure, and intended use. This discontinuity is particularly evident in state-level K–12 frameworks where some states treat collaboration as a stand-alone competency and others embed it within broader constructs such as communication, creativity, civic engagement, or leadership (Atwell & Tucker, 2024). These differences reflect locally prioritized values, but also introduce challenges for designing portable assessments, supporting student mobility across states, and achieving instructional coherence. Given these challenges, a shared theoretical foundation may support unity across states, by offering a set of core subskills with adaptable examples.

Furthermore, although existing frameworks have provided important conceptual groundwork for defining collaboration skills, few offer developmental specificity to guide learning progression across the K–12 continuum. In other words, existing frameworks do not often focus on a specific age demographic for identifying and assessing collaboration skills. For example, the Partnership for 21st Century Skills (2009) does not specify how collaborative behaviors evolve from elementary through high school, the OECD framework (2013) targets 15-year-olds without articulating a progression of skills across earlier developmental stages, and the XQ Competency Progressions (XQ, n.d.) offers developmental trajectories for competencies such as productive collaboration and negotiating conflict, which are not grade- or age-aligned behavioral indicators that clearly distinguish various levels of performance within the K–12 continuum. Among the few initiatives that explicitly attempt to articulate developmental

progressions is the Assessment and Teaching of 21st Century Skills (ATC21S) project, which proposed a learning progression for collaborative problem solving based on empirical evidence and classroom observation. While influential, ATC21S's focus was primarily on task-based performance in computer-supported environments and still may not fully capture the various ways collaboration skills can be evidenced in out-of-school learning experiences. Finally, some state frameworks also provide progressions (e.g., Kentucky Department of Education, 2024; North Carolina Department of Public Instruction, n.d.; Utah State Board of Education, 2021), but they lack coherence across states and vary in the level of skill specificity.

Our proposed framework builds on and integrates these prior efforts by offering behaviorally anchored subskill indicators that can serve as a foundation for future development of learning progressions among high school students. While the framework does not yet articulate a developmental sequence, those subskill indicators are designed to inform assessment development across varied learning contexts and support the eventual construction of empirically grounded learning progressions.

In particular, prior research has demonstrated the value of linking observable interactive patterns to underlying collaborative constructs. For example, the In-Task Assessment Framework (I-TAF; Kerr et al., 2016) captures process-oriented collaborative behaviors during task performance, while structured models that systematically link observable behaviors and discourse to latent dimensions of collaborative processes (e.g., Andrews-Todd & Kerr, 2019; Andrews-Todd & Forsyth, 2020) enable more precise interpretation of collaborative performance. These approaches informed our emphasis on defining subskill indicators as observable behaviors that can be elicited and evaluated within authentic collaborative tasks (Sun et al., 2020).

At the same time, the increasing prevalence of digital and AI-mediated environments emphasizes the importance of designing indicators that are applicable across both traditional and technology-rich contexts. Students nowadays increasingly engage in collaboration via a range of modalities, including face-to-face interaction, online communication platforms, and other AI-driven applications (Jeong et al., 2019). Systematic reviews suggest that these environments can generate rich behavioral data that can support the assessment of collaboration processes, reinforcing the need for clearly defined behaviorally anchored indicators (Chen & Chen, 2024; Cherbonnier et al., 2025; Huang & Ochoa, 2025).

In sum, our framework situates collaboration skills within both established research and emerging learning environments with the hope of providing a practical and extensible foundation for assessment and instruction. By articulating subskills through observable indicators, the framework aims to (1) strengthen the connection between theory, measurement, and practice, (2) support future work on developmental progressions and validation, and ultimately, (3) support students' long-term success in academic learning, civic engagement, and workforce readiness.

Defining and Developing a Framework for Collaboration Skills

To define and develop an updated framework for collaboration skills, we followed an approach grounded in evidence-centered design (M. Liu & Haertel, 2011; Mislevy et al., 2009), drawing from prior work on other durable skills by the authors (L. Liu et al., 2025; Ober et al., 2025; see Table 1). Central to our process was the development of a design pattern document, which synthesizes key elements of notable collaboration frameworks, existing research, current collaboration assessments, and various skill frameworks, sourced through targeted literature searches and conversations with experts in K–12 assessment (see Table S1 in Supplemental Materials for a list of reviewed frameworks). Using this design pattern document, we integrated information including definitions, subskills, related terms (e.g., coordination, cooperation, collaborative problem solving), existing frameworks, the rationale for collaboration assessment, current expectations for high school learners, focal knowledge, skills, and abilities (KSAs), both in-school and out-of-school learning opportunities, connections to K–12 disciplinary standards, assessment examples, assessment considerations, and a curated set of references.

Table 1. Stages for Conceptualizing the Collaboration Skills Definition and Framework (Adapted from L. Liu et al., 2025; Ober et al., 2025)

Stage	Description
1. Review of Existing Literature and Frameworks	• Explored existing knowledge to create a strong collaboration skills framework. • Gathered theoretical and empirical research, studied collaboration literature, and examined established frameworks. • Reviewed competency definitions and frameworks used by various states to identify similarities between definitions of the skill of collaboration and to consider potential relevant behavioral examples.
2. Synthesize and Draft a Definition	• Documented relevant information from the literature search, frameworks, and common themes using a design pattern document (M. Liu & Haertel, 2011). Such information included a summary of the literature and existing frameworks relevant to the construct, a rationale for its measurement, expectations for the focal population, and the consideration of focal subskills, among other types of information. Refined understanding and the definition of collaboration skills through continuous iteration.
3. Identify Relevant Subskills and Subskill Indicators	• Informed by the prior stages, drafted subskills in an effort to document observable features of collaboration skills likely to enable effective measurement and assessment. Distinctive dimensions of the skill of collaboration (i.e., subskills) were further defined. Within each unique dimension, observable features (i.e., subskill indicators and behavioral examples) were further identified.
4. Expert Evaluation	• Collaborated with three external skill experts, 10 educators, 3 researchers with expertise in cultural responsiveness, 2 multilingual learner experts, 2 accessibility experts, and 9 higher education and workforce professionals to review and evaluate the definition and framework for theoretical relevance, clarity, and appropriateness given the focal population. Both in-person and virtual meetings were conducted, including a two-day initial design workshop and a series of 11 virtual meetings supplemented by asynchronous feedback. This process involved iterative review of the collaboration framework alongside related skills (e.g., communication, critical thinking) to identify areas of conceptual overlap, clarify construct boundaries, and refine subskills and indicators for coherence, distinctiveness, and practical applicability across contexts.
5. Refine and Finalize	• Collaboratively discussed the overlapping features of skill definitions and frameworks. • Refined subskills and indicators through discussions and consensus-building to ensure greater precision and minimal overlap. • Minimized redundancy and ensured clarity. • Finalized the set of distinct subskills, indicators, and behaviors that capture effective collaboration.

To develop a robust and usable definition of collaboration skills and identify its critical subskills, we engaged in a multi-phase development and review process between October 2024 and December 2025. This process combined an initial in-person design workshop with multiple

rounds of expert and stakeholder review, followed by iterative refinement cycles. The process began with a two-day, in-person writing and development meeting, during which two researchers and two assessment experts collaboratively developed an initial collaboration framework, including a working definition, core subskills, and guiding design principles (e.g., observability, asset-based language, and attention to context). The meeting also drew on shared development criteria, existing collaboration frameworks, and prior design pattern documents relevant to collaboration skills.

Following this initial development phase, the framework was refined through a series of iterative review cycles involving multiple stakeholder groups, including three external skill experts, 10 educators, three researchers with expertise in cultural responsiveness, two multilingual learner experts, two accessibility experts, and nine higher education and workforce professionals. Collectively, these stakeholders brought deep expertise in educational psychology, learning sciences, psychometrics, K–12 curriculum design, and workforce readiness. A total of 11 virtual meetings were conducted across these different stakeholder groups, most of which lasted 1–2 hours in duration, supplemented by asynchronous feedback. To support productive review, stakeholders were provided with a set of guiding questions for consideration, example guidelines relevant to framework development focused on: (a) the overall quality and clarity of the framework (e.g., *What is working well?*, *What needs improvement?*, *What may be missing?*), and (b) usability across contexts (e.g., *How can the framework be used in practice?*). Additional prompts encouraged reviewers to consider age appropriateness, inclusiveness, and the extent to which the framework reflects authentic collaborative practices.

It is important to note that these expert and stakeholder reviews were conducted primarily in the service of developing learning progressions for selected skills, which will be further empirically validated and reported in subsequent work. However, the research team incorporated relevant insights from these reviews to refine the collaboration framework presented here, across four rounds of revisions. In particular, feedback related to construct clarity, the distinction among subskills, and the need for culturally responsive and context-sensitive indicators informed revisions to the framework's definition, subskills, and behavior indicators.

Across the development period, the research team met regularly (biweekly) to synthesize feedback and revise framework components. This iterative, feedback-informed process helped ensure that the framework was both theoretically grounded and practically viable across diverse

educational settings. While the experts affirmed that collaboration skills significantly intersect with related constructs, such as communication and critical thinking, they emphasized that collaboration is uniquely defined by its focus on working effectively with others toward shared goals.

Building on the iterative expert consultation process, we synthesized feedback to finalize the following definition:

> Collaboration skills are defined as the capacity to work toward shared goals through engaging in effective communication, coordinating group effort to integrate diverse perspectives, and fostering interpersonal relationships. It involves exchanging ideas openly, regulating group activities, and prioritizing building trust and respect to enable groups to leverage individual strengths while maintaining focus on collective success.

In addition, we identified three primary subskills that reflect distinct dimensions of collaboration. These subskills include engaging with ideas through intentional communication in service of shared goals (*Collab 1*), effectively engaging in and facilitating group activities and decision-making towards a shared goal (*Collab 2*), and emphasizing interpersonal relationships (*Collab 3*).

Each of the three collaboration subskills is broken down into 2-3 subskill indicators that describe specific behaviors and dispositions observable through students' verbal and nonverbal actions during collaborative processes (see Table 2 for the full list of subskill indicators and behavioral examples). Each subskill is designed to target a distinct dimension of collaboration skills. In general, the subskill *Collab 1* emphasizes communication for understanding and engaging with ideas to support shared goals, focusing on within-group comprehension and perspective-taking. *Collab 1* includes subskill indicators such as developing comprehension or understanding (*Collab 1.1*), and embracing, respecting, and elevating diverse perspectives of group members (*Collab 1.2*). *Collab 1.1* focuses on developing mutual understanding by actively clarifying, questioning, and explaining ideas to support the group's conceptual alignment. *Collab 1.2* emphasizes embracing diverse perspectives and inclusive dialogue to encourage respect and building on others' contributions, especially when ideas differ.

The subskill *Collab 2* focuses on processes involved in regulating group activities and decision-making, such as when establishing and following shared goals and norms (*Collab 2.1*), monitoring/evaluating group progress (*Collab 2.2*), and adjusting team processes and timelines

(*Collab 2.3*). *Collab 2.1* focuses on establishing and following shared goals or group norms, while actively supporting and uplifting members' strengths and experiences. *Collab 2.2* emphasizes monitoring and evaluating progress toward shared goals and timelines, including actions like prompting status updates or comparing group work. *Collab 2.3* captures adapting strategies or timelines when problems arise, such as suggesting changes to a group's goals or pivoting to address a group's needs.

Finally, the subskill *Collab 3* emphasizes the social dimension of collaborative processes, such as building trust (*Collab 3.1*) and supporting team dynamics (*Collab 3.2*). *Collab 3.1* emphasizes building psychological safety to ensure all group members feel valued and safe to contribute, including actions such as expressing appreciation, using inclusive language, or encouraging others to share alternative ideas. *Collab 3.2* focuses on supporting group functions, dependability, and effectiveness, including checking on teammates' needs or motivating peers to stay engaged.

It is important to note that the behaviors described in our framework emphasize distributed collaborative functions rather than formal leadership roles. Behaviors like "developing group goals" (*Collab 2.1*) or "combining group members' ideas" (*Collab 1.1*) can be enacted by any group member, depending on the task phase, group needs, or individual strengths. This approach distinguishes collaboration skills from hierarchical leadership, stressing that effective collaboration involves flexible, shared responsibilities to advance group goals.

Table 2 presents the full set of collaboration subskill indicators along with concrete observable example behaviors for each subskill that may be demonstrated by high school students. This detailed description offers a clear reference point for educators, students, and researchers, providing a basis for understanding what effective collaboration looks like, supporting formative feedback generation and instructional planning, and improving consistent measurement and documentation.

Table 2. Collaboration Skills Framework Showing Subskills, Subskill Indicators, and Example Behaviors

Subskills	Subskill Indicators	Example Behaviors
Collab 1: Engaging with ideas through intentional communication in service of shared goals	Collab 1.1: Develop comprehension or confirm understanding in multidimensional ways	• Asks questions that help the group understand and use diverse ideas and perspectives including those from personal or cultural experiences • Acknowledges what group members have shared to ensure accurate understanding (e.g., restates information shared by group members).
	Collab 1.2: Embrace, respect and elevate diverse perspectives and ideas	• Compares and combines different ideas by showing how they are similar, different, or strong in different ways • Creates new ideas and solutions by combining different parts of group members' contributions • Engages in conflicts constructively and works with group members to include different viewpoints in group solutions and expresses vulnerability about their own viewpoints
Collab 2: Effectively engaging in and facilitating group activities and decision-making towards a shared goal	Collab 2.1: Flexibly establish and follow group goals and team norms	• Develops group goals and explains how they connect to everyone's strengths and abilities • Contributes flexibly to support group goals, adapting to roles in ways that reflect individual experiences and cultural strengths • Shows respect by actively listening, trying to understand and use different perspectives, to advance group goals
	Collab 2.2: Checking in and circling back with group progress	• Checks on the group's progress and suggests changes to goals when needed • Helps the group reflect on its overall progress toward its goals and identify areas for improvement • Suggests and uses tools to help the group stay on track
	Collab 2.3: Adjust team processes and timelines	• Works with team members to adjust task assignments or create new timelines to make progress toward the group's goal or task • Suggests and uses new tools and strategies to make progress toward the group's goal or task
Collab 3: Emphasizing interpersonal relationships	Collab 3.1: Build trust	• Builds trust by making sure everyone feels valued and respected, even if they disagree • Gives helpful feedback and shows appreciation for others' efforts to foster a flexible team environment where members feel safe to express

		disagreements, ask hard questions, and engage in honest dialogues even when discussion is challenging.
	Collab 3.2: Support team dynamics	• Demonstrates commitment (e.g., through interactions) to varied means of communication to create an inclusive environment • Provides helpful contributions to keeping the group focused and productive • Adjusts to group members' communication preferences and/or styles

Educators, curriculum designers, and assessment developers may find this framework a valuable foundation for teaching and assessing collaboration in ways aligned with local priorities while supporting broader educational goals. Feedback from these interest holders is critical for further validation, adaptation, the creation of age-appropriate progressions, and the development of assessments based on the existing framework. Its hierarchical structure, including a core definition, subskills, and subskill indicators with behavioral examples, offers both stability and adaptability. The central definition and subskills ensure coherent conceptualization of the skill, while the behavioral indicators can be tailored, expanded, or further contextualized to reflect specific cultural values, instructional settings, or policy goals. For example, a state emphasizing civic engagement might elaborate *Collab 3.2* (supporting team dynamics) to include behaviors observed in community-based service projects, whereas a district prioritizing STEM education might contextualize *Collab 2.2* (monitoring group progress) within engineering design challenges. The balance between conceptual consistency and customization enables the framework to support equity in assessment and instruction, ensuring that all learners are recognized for their collaborative strengths, even as those strengths are expressed differently across settings.

Considerations for Assessment

Several factors should be considered when applying the proposed framework for meaningful assessment of collaboration skills. These considerations reflect that collaboration is a context-dependent construct and should be assessed in ways that are authentic and appropriate for diverse K–12 learners. Assessment design should be guided by four interrelated factors: (1) the size and nature of group interactions (e.g., dyadic tasks, small-group simulations, or interactions with human vs. AI agents), (2) assessment type (e.g., self-assessments, peer, or

instructor evaluations, or scenario-based measures such as situational judgment tests [SJTs]), (3) assessment context (e.g., in-school or out-of-school settings, virtual or in-person settings, cross-cultural contexts), and (4) implementation of skills assessments (e.g., how assessments are integrated into instruction, supported by technology, and used for formative or summative purposes). Across all these factors, it is essential to account for the social, cultural, and technological contexts in which learners develop and demonstrate collaboration subskills. For example, opportunities to engage in collaborative work may vary significantly across classroom structures, language proficiency, access to digital tools, and cultural norms regarding group participation. Assessments that fail to consider these factors risk privileging certain demonstrations of collaboration skills over others, thus undermining the fairness and validity of collaborative measures.

Redefining collaboration skills also calls for assessments that capture the process-oriented nature of the construct. By emphasizing specific observable behaviors linked to the subskills in our framework, assessments may provide opportunities to elicit the multidimensional nature of collaboration skills. The subskill indicators further support the development of assessment tasks that cover a broad range of collaborative activities, offering multiple and varied opportunities for students to demonstrate their collaborative competencies. For example, a student who may be less verbally expressive in whole-group settings might show strong collaborative skills through asynchronous comments. Another student might excel at resolving conflicts in peer discussions but struggle with initiating ideas. Without opportunities to demonstrate collaboration skills across different tasks involving various roles or modalities, these important dimensions of the construct may be overlooked.

Taking each of these factors into consideration can support the design of high-quality assessments that have the potential to capture learners' collaboration skills accurately and fairly, thus better ensuring their use for identifying opportunities to support learners' skill development. In the sections that follow, we review each of these assessment considerations.

Collaboration Format: Interacting with Human and/or Computer Agents

Collaboration formats may include individuals within pairs (dyads), groups of three or more individuals, as well as with either human or computer agents (Kyllonen et al., 2017). Each of these formats offers distinct affordances and challenges for assessing collaboration skills, and

the choice of format should be driven by the specific subskills and skill indicators targeted by the assessment.

Collaboration with Varying Group Sizes. Some collaborative tasks may focus specifically on the processes or outputs that emerge from pairs or dyads. Dyadic collaboration tasks, which involve two people working together, often involve highly interpersonal interactions that require mutual trust, effective coordination, and shared responsibilities. Assessment of dyadic collaboration may examine how well pairs communicate, resolve conflicts, negotiate roles, and achieve consensus (Graesser et al., 2020). Dyadic interactions often reveal specific collaboration dynamics like reciprocal feedback, turn-taking, and collaborative problem-solving strategies, offering an ideal context for a deeper analysis of interpersonal communication and teamwork (Yuan et al., 2019).

In assessments of collaboration skills that focus on activities among larger groups (including three or more individuals) or even organizations of individuals working toward a shared goal, the focus might be on many of the same factors relevant to dyads (e.g., group dynamics, assignment of leadership roles, distribution of tasks, and shared accountability), though with added complexity given more members and the possibility of subgroup formation. Such tasks provide a context for complex interaction patterns, such as subgroup formation, distributed leadership, and collective decision-making (Drescher et al., 2014). Additionally, they may assess how effectively the group leverages individual strengths, manages conflict, and adapts to evolving group needs (Fonteijn & Dolmans, 2019). For example, Hao et al. (2024) studied interactions among four team members on a collaboration task where they used a chat feature to problem solve and choose the best option given the novel pieces of information provided to each team member. In this study, participants engaged in a variation of the jigsaw activity (see Aronson, 2002), during which they each contributed novel insights to the team to discuss and achieve a consensus.

Human-Human versus Human-AI Collaboration. In human-human collaboration formats, individuals work together toward a common goal, and assessment tasks designed to capture collaboration skills may focus specifically on evaluating an individual's engagement in group activities (Cen et al., 2016; van Aalst, 2013). Such tasks typically assess how well someone communicates ideas, listens actively, negotiates meaning, and contributes to collective outcomes through shared decision-making and coordination (Swiecki et al., 2020). In tasks that

involve this format, an individual's role within a larger group is evaluated based on their contributions to collective outcomes achieved through processes involving decision-making, problem solving, and coordination (Kyllonen et al., 2017).

While most research on collaboration assessments has focused on human-human interactions, there is growing interest in exploring the potential of human-AI collaboration as a viable and scalable alternative for eliciting evidence of collaboration skills. Tasks that involve non-human agents, such as rule-based or AI-powered systems, have been used to simulate collaborative problem-solving scenarios and examine how individuals engage with those digital agents (e.g., Edwards et al., 2025; Hao et al., 2025; Herborn et al., 2020). A notable example is the PISA Collaborative Problem Solving (CPS) assessment (OECD, 2013), which featured predefined interactions with computer agents to standardize interactions across test-takers. One advantage of using non-human agents is that they provide consistent and replicable interaction patterns, making it easier to compare performance while reducing the logistical demands of coordinating human partners. Although such simulations do not fully capture the richness and unpredictability of human-human dynamics, some early evidence suggests that learners may exhibit comparable patterns of collaborative behavior when interacting with computer agents (Herborn et al., 2020). More recent studies demonstrate that thoughtfully designed AI agents can scaffold metacognitive regulation and group coordination during group tasks (Edwards et al., 2025) and that human-AI teaming can support collaborative problem solving and learner agency in ways that resemble and, in some cases, extend collaborative engagement beyond what is typically observed in human-human collaboration contexts (Schmutz et al., 2024).

It is important to clarify that while human-AI collaboration may require certain adaptations to interaction strategies (e.g., calibrating trust or recognizing AI limitations), we do not assume it entails fundamentally different learning goals or evaluative standards from human-human collaboration. Rather, we view human-AI interaction as a complementary format and an increasingly relevant context for assessing collaborative competencies, offering great scalability and control. Given the growing use of AI in educational and workplace settings (Wilson & Daugherty, 2018), assessing students' ability to collaborate with both human and AI partners reflects realistic and future-facing demands.

As human-AI interactions become increasingly embedded in daily tasks, the ability to collaborate effectively with AI is emerging as a distinct and necessary future-ready competence.

Unlike human-human collaboration, human-AI collaboration requires individuals to interact with agents that possess limited social awareness, communicate probabilistically, and often operate with limited transparency in their reasoning (von Davier & Burstein, 2024). In this context, effective collaboration involves not only contributing ideas and coordinating actions, but also interpreting AI feedback, calibrating trust in algorithmic suggestions, and adapting one's behavior based on the affordances and limitations of the AI partner (Reverberi et al., 2022). Recognizing the affordances and limitations of AI partners is crucial for successful human-AI collaboration. This may be evidenced in behaviors that reflect evaluating AI-generated input, recognizing algorithmic bias, communicating reasoning when AI suggestions diverge from their own, and calibrating reliance on AI (Okamura & Yamada, 2020).

Our framework acknowledges both traditional human-human collaboration and emerging forms of human-AI collaboration as relevant contexts for assessing students' collaboration skills. Importantly, not all human-AI interactions are collaborative. Some are transactional, such as querying a chatbot for information without requiring mutual adaptation or shared problem solving. The goal is to capture students' capacity to engage meaningfully with diverse partners, human or AI, in the service of shared outcomes. Designing assessments that simulate or embed AI partners (e.g., conversational agents or intelligent tutoring systems) provides unique opportunities to evaluate these important collaboration capacities.

Assessment Types for Capturing Collaboration Skills

A variety of assessments can be used to capture collaboration skills. More traditional approaches, such as self-assessments, peer and instructor evaluations, and situational judgment tests (SJTs), are often widely used and remain valuable for triangulating evidence and validating the skill taxonomy. Yet, technology-enhanced assessments offer new opportunities to capture the complex and multidimensional nature of collaboration skills, and there is a growing consensus that computer-based tasks, such as simulations or game-like tasks, provide more authentic, process-oriented measures of collaboration skills (Graesser et al., 2022; Hao et al., 2024; OECD, 2017). These assessment types immerse students in dynamic, often problem-based contexts, where collaboration skills are required to progress, allowing for the collection and analysis of collaborative acts evidenced in interaction patterns (e.g., dialogue, decisions, coordination, etc.) that can be analyzed using human-coded rubrics or automated methods such as AI-enhanced analytics (Andrews-Todd et al., 2022; Flor & Andrews-Todd, 2022).

Ideally, a combination of assessment types should be considered and applied to best capture the multifaceted nature of students' collaboration skills, considering the dynamic nature of collaboration, which requires cognitive, attitudinal, and behavioral skills. We discuss relevant measurement-related and practical considerations for different types of assessments of collaboration skills in the sections that follow.

Self-Assessments. Self-assessments typically measure collaboration skills by presenting first-person worded statements (e.g., "*I provide feedback to my group members.*") with Likert-type scale response options (e.g., 1 = Never, …, 5 = Always; see Aguado et al., 2014; French et al., 2016; The Academy for Co-Teaching and Collaboration, 2012; Zhuang et al., 2008). When carefully designed considering psychometric principles, these assessments can provide reliable and valid evidence of various facets of collaboration skills (e.g., French et al., 2016; Zhuang et al., 2008). Self-assessments are also easy to administer and generally more time efficient. However, self-assessments can produce inaccurate scores due to overconfidence biases (Dunning et al., 2004), difficulty evaluating skills reliably (Taylor, 2014), and other forms of measurement bias, such as response style effects (van Vaerenbergh & Thomas, 2013). Responses may also be distorted intentionally, such as when test takers respond in a potentially self-enhancing or self-effacing manner (MacCann et al., 2011).

Peer and Instructor Evaluations. Peer and instructor evaluations offer an alternative to self-assessments for measuring collaboration skills (e.g., De Wever et al., 2011; Herro et al., 2017), given that group members and instructors can observe and provide feedback on these skills. However, instructors may face challenges evaluating learner collaboration skills due to the difficulty of simultaneously observing multiple learners (Zhang et al., 2008). Furthermore, both peer and instructor evaluations are susceptible to cognitive biases, such as the halo (or horn) effect, which occurs when positive (or negative) impressions of a person bias other evaluations in the same direction (Nisbett & Wilson, 1977). These biases present measurement-related considerations that need to be accounted for when assessing collaboration skills (see Jin & Eckes, 2025). Thus, assessments that encompass responses from multiple raters (i.e., feedback from peers, instructors, and self) may provide a more complete picture of collaboration skills (Tee & Ahmed, 2014), but still require appropriate psychometric analysis to ensure that the dimensionality of collaboration skills is not impacted by irrelevant forms of measurement bias.

Situational Judgment Tests (SJTs). As an alternative to assessments that involve evaluations of others, SJTs may be used to assess how individuals respond to collaboration-oriented scenarios. This type of assessment requires test takers to review a scenario targeting a specific skill and then rate the effectiveness of various response options. SJTs are highly flexible and can be tailored to the purpose of the assessment by varying features such as the number of response options, instructions, how options are scored, and the scale format (e.g., Arthur et al., 2014; De Leng et al., 2018; Ployhart & Ehrhart, 2003). SJTs can be time consuming and costly to develop because they require subject matter experts to design, review, and test items, but when applied in practice, SJTs have been found to exhibit favorable psychometric properties for assessing complex skills such as collaboration (Patterson et al., 2012, 2016).

When it comes to capturing certain dimensions of collaboration skills, SJTs may offer specific advantages. Unlike performance-based assessments that require coordinating multiple participants, SJTs can efficiently assess an individual's collaborative judgment and decision-making, such as when recognizing effective versus ineffective collaborative strategies across varied scenarios (Patterson et al., 2016; Zhuang et al., 2008). Despite these strengths, SJTs may still be vulnerable to biases related to faking, coaching, and practice effects (see Lievens et al., 2008) and are unlikely to fully capture the dynamic, interpersonal nature of actual collaborative interactions. When considering these strengths and limitations, SJTs may be most useful as one component of a multi-method assessment approach: they can screen for collaborative competence at scale, identify areas for targeted skill development, and complement performance-based measures that capture real-time collaborative behaviors.

Computer-Based Assessments. Research in computer-supported collaborative learning and AI-enhanced environments has advanced the use of computer-based assessments as a dynamic and process-oriented approach to assessing collaboration skills. These assessment types, such as simulations, digital scenarios, and multiplayer games, allow students to engage in authentic tasks that generate rich behavioral data. Critically, these assessment types are increasingly paired with process-based analytic methods to evaluate collaborative performance. For example, data generated from simulation or game-based tasks can be analyzed using natural language processing (NLP), machine learning, learning analytics, and collaborative scripts to assess dimensions such as discourse quality, coordination, and metacognitive regulation, all of

which may be relevant for gauging collaborative interactions and processes (Huang & Ochoa, 2025).

Simulation-based assessments, such as PISA CPS tasks (OECD, 2017), create interactions with AI agents to assess students' decision-making, responsiveness, and information sharing in dynamic contexts. Conversation-based tasks have been used to elicit collaboration skills, with researchers applying NLP and AI models to analyze chat logs, action sequences, and role coordination (e.g., Andrews-Todd et al., 2022; Flor & Andrews-Todd, 2022; Hao et al., 2024). Process-oriented tools may enhance these assessment types. For example, learning analytics dashboards embedded in collaborative assessment platforms can provide visualizations of participation and coordination, supporting both formative feedback and summative scoring (Yang et al., 2024). Scripted roles and collaborative prompts (Schnaubert & Vogel, 2022; Strijbos, 2011) embedded within digital assessments could structure group work and allow targeted measurement aligned with specific subskills. Large language models (LLMs) can now be used to automatically code collaborative discourse at scale (Hao et al., 2024), offering new potential for real-time scoring and feedback on collaboration skills.

When assessing collaboration skills, more traditional assessment types remain useful for capturing and validating attitudinal, cognitive, and behavioral evidence of collaboration skills. At the same time, computer-based assessments and AI-based tools offer great opportunities for measuring collaboration skills dynamically and efficiently at scale.

Strategies for Assessing Collaboration Skills in Authentic Contexts

Students' learning and performance in collaborative activities are likely to vary based on other factors, such as group dynamics and other psychosocial variables, as well as the subject or context in which the collaborative task is taking place (Vives et al., 2024). Assessments of collaboration skills can occur in school settings, such as through course assignments and projects involving complex problem solving, or during out-of-school activities, such as internships, extracurricular activities, and community-based events. Out-of-school assessments may be less standardized, but they have the benefit of providing opportunities to evaluate collaboration skills in tasks mirroring authentic, real-world settings (e.g., Lee, 2013) and may reflect proficiency in skills not otherwise recognized in traditional academic contexts (e.g., certifications; Werquin, 2010). In either context, collaborative activities may occur in-person or virtually, raising unique considerations for assessment. Many of the issues discussed in previous sections apply to both in

person and virtual/online collaborative interactions. Ideally, students' collaboration skills are developed and assessed across authentic contexts using multimodal assessments to provide a rich understanding of these skills.

It is also important to consider how factors related to varying social and cultural contexts may influence the appropriateness of assessment design. Different cultures may have different norms, values, and expectations for what constitutes appropriate behaviors conducive to collaboration (Grossman et al., 2021; Hofstede, 2011). For example, some collaboration scenarios (e.g., employees interacting with their boss) may have different norms for acceptable behavior across cultures. Such differences may influence employee expectations regarding whether to follow orders and their openness to interactions with their bosses (Hofstede, 2011). Furthermore, individuals from cultures that tend to feel uncomfortable with ambiguity and uncertainty (preferring clear rules and structured environments), a concept referred to as *uncertainty avoidance*, may want more structure in team planning and check-ins (Burke et al., 2017). Such differences suggest the need to adapt subskill indicators to specific cultural contexts or when working with cross-cultural teams. Thus, considering assessment context fidelity and cultural norms may support the validity and fairness of authentic collaboration assessments.

Implementing Assessments of Collaboration Skills in Classrooms

The successful implementation of assessments of collaboration skills in real educational contexts depends on coordinated support from key interest holders such as educators, researchers, governing bodies, and learners. The collaboration skills framework introduced in this paper offers behaviorally anchored indicators that help educators observe, measure, develop, and provide formative feedback on student collaboration skills. Professional learning programs can be designed to help educators interpret evidence of collaboration skills, integrate the framework into daily teaching practices, and use assessment data to inform pedagogy. Researchers can use the framework to design, pilot, and validate assessments of collaboration skills across diverse educational contexts. Their role includes generating empirical evidence on multiple collaboration subskills, testing their applicability across contexts, and ensuring psychometric soundness in the measurement of collaboration skills.

State departments and district leaders can play a critical role in setting standards and shaping implementation at scale. The development of our collaboration skills framework helps align existing and emerging state PoGs which prioritize collaboration as a key skill, including

those mentioned previously, with concrete indicators to monitor student growth and provide system-level support for educators. For example, the 12th grade framework for Kentucky recognizes that productive collaboration involves cooperation in making team decisions (similar to *Collab 2.3*), recognizing individual contributions to team goals (similar to *Collab* 2.1), engaging with diverse perspectives (*Collab* 1.2), and giving and receiving constructive feedback (*Collab* 1.1; Kentucky Department of Education, 2024). The framework for the state of Washington frames collaboration as part of communication, calling for students to work on a team that leverages members' strengths to achieve collective group goals (*Collab* 3.*2*), work with people who share diverse voices, skills, and views (similar to *Collab* 1.2), as well as navigate conflict effectively (similar to *Collab* 1.2; Muller, 2021). This alignment can support consistency in instruction and the development of collaboration assessments, ultimately allowing for clear and measurable ways to track and benchmark student growth. For learners, the framework can guide self-directed skill development by supporting students in identifying their collaboration strengths and potential areas for improvement.

Discussion and Future Directions

Collaboration is increasingly recognized as critical for success across academic, civic, and workplace settings. It not only supports cognitive and situated learning (e.g., Andrews & Rapp, 2015; Jeong et al., 2019), but also contributes to social development (Laal & Ghodsi, 2012; Tolmie et al., 2010) and long-term career outcomes (e.g., Rios et al., 2020). As more than 40 U.S. states have adopted PoG frameworks that emphasize durable skills like collaboration (Atwell & Tucker, 2024), there is a growing need to intentionally integrate these skills into K–12 instruction and assessments. Yet, few existing frameworks offer clear guidance with specific, observable, and measurable performance indicators that educators can use to guide instruction and provide feedback. The proposed framework addresses this gap by identifying key collaboration subskills and providing behaviorally anchored indicators that can guide assessment and instructional design.

We articulate several assessment types and contexts useful to capture various dimensions of collaboration skills, while considering key design principles for reliable, valid, and fair assessments, aligned with the Standards for Educational and Psychological Testing (AERA, APA, and NCME, 2014). By design, the framework aims to support the integration of skill

development into curriculum, moving beyond conceptual descriptions toward concrete tools for practice.

Future research should study how students' collaboration skills evolve over time and across contexts to establish a learning progression that captures meaningful growth trajectories in real learning environments. With that in mind, we emphasize that the framework proposed in this paper requires validation by the stakeholders who will use it in practice, across different grade levels and contexts. State education agency representatives, district leaders, curriculum designers, and classroom teachers should evaluate whether the framework meets their needs for developing learning tasks, providing instructional guidance, and designing assessments. Assessment developers should examine whether the subskills and indicators provide sufficient clarity and distinctiveness to support reliable measurement. Feedback from these groups may reveal needed refinements to enhance the framework's practical utility.

Important psychometric considerations remain to be addressed in future research and assessment development. Empirical studies examining the distinctiveness of the subskills will be essential to validate the proposed structure and determine whether the subskills function as theoretically unique dimensions in practice. Moreover, a critical question is whether collaboration should be modeled as a unidimensional or multidimensional construct with correlated subskills. We currently conceptualize collaboration skills as multidimensional, with three distinct but interrelated subskills. However, empirical validation through psychometric methods is needed to test whether the proposed three-factor structure provides a better fit than alternative models (e.g., unidimensional, hierarchical, or bifactor models). Additional considerations include optimal test length to balance comprehensive coverage of subskills with practical administration constraints, scoring methods (e.g., dichotomous vs. polytomous, holistic vs. analytic rubrics, etc.), and scaling approaches (e.g., classical test theory vs. item response theory [IRT], unidimensional vs. multidimensional IRT models, etc.). The choice of scaling method has implications for score interpretation, growth modeling, and the ability to provide diagnostic feedback on specific subskills.

Finally, emerging technologies offer promising opportunities to assess collaboration skills at scale, while also raising novel concerns. One opportunity is to explore the use of innovative technologies to improve assessments of collaboration skills that embrace cross-cultural differences, while ensuring assessment accuracy and fairness. Although promising, using AI

applications in assessments of collaboration skills also raises ethical concerns, such as those related to privacy and bias, that must be carefully addressed to ensure their effective and equitable implementation and use in educational systems (Nguyen et al., 2023). Future research should continue to explore the best uses of AI for assessing collaboration skills in a manner that ultimately supports learners with minimal risk. Careful consideration and development of innovative, holistic, and psychometrically sound assessments of collaboration skills in K–12 settings are needed to support learners in developing the skills needed to thrive in socially dynamic environments.

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Supplemental Materials

Table S1. Exemplar Collaboration Frameworks Reviewed

Framework	Focus/Definition of Collaboration	Citation
XQ Framework	XQ has a competency "Generous collaborator for tough problems" that contains the following subcompetencies: social awareness (recognizing and valuing diverse perspectives, managing social dynamics), interpersonal skills (building healthy relationships, navigating conflict, developing empathy, collaborating productively), and social agency (advocating for and inspiring oneself and others).	XQ Institute (2022)
Pearson Collaboration Skill Framework	The Pearson Collaboration Skill Framework contains three subskills and learning progressions. The three subskills are (1) engaging with ideas (listening to others, building on group ideas, reaching consensus), (2) interpersonal communication (providing and receiving feedback, building norms), and (3) task management (managing group responsibilities, completing tasks, managing challenges).	Pearson (2022)
International Society for Technology in Education (ISTE)	ISTE's "Global Collaborator" uses "digital tools to broaden their perspectives and enrich their learning by collaborating with others and working effectively in teams locally and globally." Subskills include connecting with peers from diverse backgrounds, using technology to approach problems from multiple viewpoints, working towards a group goal, and exploring local/global issues.	ISTE (2024)
Partnership for 21st Century Skills Framework	This framework views collaboration as a learning and innovation skill. To collaborate with others involves: "Demonstrate ability to work effectively and respectfully with diverse teams," "[e]xercise flexibility and willingness to be helpful in making necessary compromises to accomplish a common goal," and "[a]ssume shared responsibility for collaborative work, and value the individual contributions made by each team member."	Partnership for 21st Century Skills Framework (2009)
America Succeeds: Durable Skills Advantage Framework	Collaboration is listed as a durable skill (teamwork and connection). Collaboration is viewed as a competency/theme and the following are durable skills that fall within this theme: Interpersonal communication, coordinating, teamwork, scheduling, team oriented, team leadership, collaboration, team building, cooperation, and virtual teams.	Cole et al. (2021)
European Commission: The LifeComp Framework	Lifecomp provides three competence areas (personal, social, and learning to learn) with nine competencies, one of which is collaboration. Specifically, collaboration is one of three social competencies and defined as, "engagement in group activity and teamwork acknowledging and respecting others."	European Commission (2020)
EBSCO Competency Center Framework	EBSCO defined collaboration as "Work[ing] effectively with others to broaden perspectives and work toward common goals." This involves the following skills: "Create: Learners participate in personal, social and intellectual networks by: III.B.1 Using a variety of communication tools and resources." and "Share: Learners work productively with others to solve problems by: III.C.2 Involving diverse perspectives in their own inquiry processes."	EBSCO Connect (2026)
Kentucky Portrait of a Learner	Kentucky Department of Education defines a "Productive Collaborator" as someone who "[e]ngages with others to achieve a	Kentucky Department

	common goal through building positive relationships, actively listening, showing empathy and making individual contributions to a larger group." Subskills include the following: "Uses cooperative processes to make decisions and achieve desired outcomes," "[r]ecognizes individual contributions and the contributions of others," "[e]ngages with different perspectives/ideas to develop empathy and resolve conflicts," and "[g]ives, receives and implements constructive feedback."	of Education (2024)
North Carolina Portrait of a Graduate	North Carolina Department of Public Instruction's rubric defines collaboration by stating: "North Carolina Graduates… Contribute and respond to diverse perspectives to achieve a common goal. Leverage strengths to resolve conflict and foster teamwork. Interact respectfully with others in digital and in-person interactions. Embrace a variety of roles in a group as a participant and a leader." Progressions include creating clear agreements, clearly defining roles and flexibly taking on roles, facilitating conflict resolution, and maintaining productivity and accountability.	North Carolina Department of Public Instruction, n.d.
Utah Portrait of a Graduate Competencies	Utah's Board of Education defines "Collaboration and Teamwork" as "contribut[ing] ideas, perspectives and experiences to cultivate a community of shared accountability and leadership." They outline two progressions that specify the following for 9-12th grade students: (1) "Students will be able to contribute to and work effectively in teams by leveraging various tools and resources, adapting to multiple roles and facilitating connections of diverse perspectives to accomplish shared goals" and (2) "Students will be able to create shared responsibility for collaborative work and value the individual contributions made by each team member to cultivate a culture of community."	Utah Board of Education (2021)

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