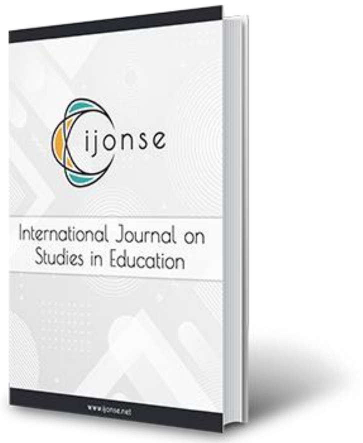

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Beyond the Acronym: Interlacing STEAM, Special Education, and Guiding Inquiry

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Beyond the Acronym: Interlacing STEAM, Special Education, and Guiding Inquiry

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Abstract

Interlacing STEAM and special education fosters inclusive, adaptive learning environments for special needs learners that support interdisciplinary and transdisciplinary instruction. The interwoven nature of STEAM enhances engagement, accessibility, and problem-solving for all learners, including students with disabilities. Constructivist methodologies, inquiry-based learning, and multimodal instruction ensure that STEAM extends beyond content knowledge to cultivate critical thinking, creativity, and self-efficacy. Assistive technologies, child-computer interactions, and digital fabrication provide pathways for diverse learners to participate in meaningful, inquiry-driven learning experiences. Intentional scaffolding supports students with varied cognitive and physical abilities, reinforcing engagement and accessibility. Professional erudition serves as a model for enhancing teacher capacity, combining targeted professional development with sustained, site-based professional learning. Findings indicate that STEAM education, when interlaced with special education, creates a responsive learning framework that empowers all students, strengthens interdisciplinary collaboration, and fosters accessibility. Recognizing STEAM and special education as interconnected rather than disparate disciplines ensures that learning remains dynamic, inquiry-driven, and inclusive for all students.

Introduction

Education in the 21st century increasingly requires approaches that move beyond isolated subject areas, fostering deeper connections across disciplines to better address complex, real-world challenges. Two critical frameworks for achieving this integration are interdisciplinary and transdisciplinary learning. Interdisciplinary education involves interlacing knowledge and methods from multiple disciplines to address a specific issue, allowing students to make connections across fields (Liao, 2016). Collaboration between distinct subject areas remains central to interdisciplinary learning while ensuring that each discipline maintains its integrity (Bloomquist & Georges, 2022).

In contrast, transdisciplinary education moves beyond disciplinary boundaries entirely, merging knowledge and methodologies to create new ways of understanding and solving problems (Clark & Button, 2011). Holistic thinking is at the core of this approach, emphasizing shared learning among educators, students, and the broader community (Barth et al., 2023). Both interdisciplinary and transdisciplinary methods serve as the foundation of interlaced science, technology, engineering, art, and mathematics (STEAM) education, promoting creativity, innovation, and problem-solving through interwoven and hands-on learning experiences.

STEAM education provides an ideal framework for these approaches, blending science, technology, engineering, arts, and mathematics in ways that cultivate deeper engagement and understanding (Tytler, in press). Unlike traditional STEM models, which often focus on discrete technical skills, STEAM interlaces disciplines by emphasizing reciprocal connections that extend beyond content knowledge to include cognitive, social, and creative dimensions. Rather than treating disciplines as isolated domains, interlacing recognizes the fluidity between them, reinforcing their intersections while maintaining their distinct contributions. Academic success, critical thinking, and adaptability emerge as natural outcomes, strengthening STEAM's effectiveness for supporting diverse learners, including those in special education and those benefiting from personalized learning approaches.

An interlacing approach to STEAM and special education positions both as equally valuable components that, when woven together, create accessible, inclusive, and meaningful learning experiences. Viewing these frameworks as interlaced rather than separate ensures that learning remains dynamic, adaptable, and inquiry-driven. Maintaining the distinctiveness of each discipline while reinforcing their connections allows for a responsive model that acknowledges the complexity of student learning and the need for flexible, inclusive instruction.

STEAM for Engaging All Learners

STEAM education fosters a dynamic and inclusive learning environment by interlacing multiple disciplines to enhance student engagement and learning outcomes (Liao, 2016). Leveraging **interdisciplinary** strategies in STEAM learning environment allows students to connect knowledge from different domains, encouraging them to think critically and solve problems through hands-on, project-based learning (Rabin et al., 2021). Arts integration, a key component of STEAM, enhances this interdisciplinary approach by offering students creative pathways to explore scientific and mathematical concepts (Henriksen, 2017).

In addition to interdisciplinary learning, STEAM also supports **transdisciplinary** collaboration, where knowledge is co-constructed rather than confined to traditional subject boundaries (Clark & Button, 2011). An interlaced approach promotes authentic, problem-based learning that reflects real-world challenges, making it particularly effective in engaging diverse learners, including those with special needs (Barth et al., 2023). Emphasizing both interdisciplinary connections and transdisciplinary problem-solving creates a flexible STEAM educational framework that accommodates a wide range of learning styles and abilities, ensuring all students have access to meaningful learning experiences (Liao, 2016). Key features of interdisciplinary and transdisciplinary teaching and learning for STEAM and special education are summarized in Table 1: Focus, Discipline Boundaries, Role in STEAM, Application in Special Education, and Inquiry Emphasis.

Table 1. Key Features of Interdisciplinary and Transdisciplinary STEAM Approaches

Aspect	**Interdisciplinary**	**Transdisciplinary**
Focus	Integrating knowledge across distinct disciplines	Merging disciplines to form new knowledge frameworks
Discipline Boundaries	Maintained with collaboration	Dissolved or merged completely
Role in STEAM	Enhances connection between domains (e.g., math + art)	Leads to emergent learning outcomes beyond subjects
Application in Special Education	Supports differentiated instruction through multiple domains	Empowers student-led learning via flexible design
Inquiry Emphasis	Domain-specific questions with crossover	Real-world problems without disciplinary constraints

Special Education for Supporting All Learners

Special education frameworks are designed to provide learning opportunities for all by adapting instructional methods to meet the needs of diverse learners. STEAM education complements special education by fostering an inclusive environment where students can engage with content through multiple modalities, including visual, auditory, and kinesthetic learning experiences (Clark & Button, 2011). The transdisciplinary nature of STEAM supports differentiated instruction by allowing educators to tailor content to students' individual strengths and challenges, ensuring accessibility and engagement (Bloomquist & Georges, 2022). Furthermore, collaborative learning within STEAM fosters a sense of community and shared inquiry, providing students with disabilities opportunities for social and academic growth in authentic, hands-on experiences (Clark & Button, 2011). Interlacing STEAM within special education enhances students' self-efficacy and problem-solving abilities while bridging gaps in traditional instructional approaches (Liao, 2016).

Personalized Learning

Personalized learning within STEAM frameworks supports individualized educational experiences by leveraging students' interests, strengths, and needs to guide instruction. Inquiry-driven and project-based methodologies in STEAM education encourage autonomy, allowing students to take ownership of the learning while receiving targeted support (Jia et al., 2021). The interlacing of STEAM with special education further reinforces the importance of flexible, student-centered instruction that promotes metacognition and engagement through hands-on, contextual learning (Rabin et al., 2021). The emphasis on interdisciplinary collaboration within STEAM also fosters critical thinking and creativity, equipping students with the adaptive skills necessary for lifelong learning and problem-solving in an ever-changing world (Tytler, in press). Personalized learning within a STEAM context empowers all learners by providing accessible and meaningful opportunities to connect knowledge with real-world applications (Jia et al., 2021).

Interlacing Cognition and Regulation

Social capital in STEM improves students' academic learning, motivation, and participation by providing learners with emotional resources within their social networks (Saw, 2020). The construction of social capital provides a pathway for learners to work together to achieve learning outcomes. STEAM enhances social capital in students by promoting collaboration, communication, and teamwork, which are fundamental competencies for achievement in academic and professional environments (Allina, 2018). The inclusion of the arts in STEM to STEAM creates opportunities for students to employ creativity in learning and for sharing innovative ideas with peers, resulting in emotional awareness and self-assurance. Interlaced relationships create social networks in a mutually supportive environment for nurturing both social capital and self-confidence. Social capital in STEM classrooms is important for nurturing supportive networks and resources that positively impact students' academic performance, emotional regulation, and self-confidence (Basham, et al. 2010; Puccia et al., 2021).

STEAM and Personalized Learning

STEAM Education

STEAM education supports personalized learning by allowing students to connect with material individually and meaningfully. Students who can connect with the content in a meaningful way have a better conceptual understanding that allows for an increase in self-efficacy. Self-efficacy and building capacity allow students to engage with the materials to create background context and promote creativity. Providing students and teachers with the tools to explore and create within the STEAM education setting fosters collective efficacy, and more opportunities for real-world problem-solving can be activated (Conradty & Bogner, 2020; Moon et al., 2012).

Intentional Planning

Intentional planning helps to support scaffolding to support student learning. As students use interlaced curricula to learn, the information explored allows for meaningful connections to be made. Meaningful learning with interdisciplinary connections translates into intrinsic motivation to learn using creativity to address real-world problems. Students create meaningful solutions through curiosity and exploration. The ability to explore through curiosity allows for meaningful interactions with the materials, building the self-efficacy of the learning. When students find meaning in the information provided, the information becomes a part of their schema and allows for interdisciplinary connections and social-emotional efficacy. The ability to learn and apply concepts and assign meaning promotes self-efficacy and a sense of inclusion (Best et al., 2019).

The Learning Environment

Constructivism is a foundational educational theory that emphasizes learners' active role in assembling knowledge through meaningful experiences. Unlike traditional transmission-based models, constructivism asserts that learning occurs as individuals connect new information to existing cognitive structures, or schemas, through exploration, inquiry, and reflection (Zhu & Atompag, 2023). A constructivist approach fosters deeper understanding by engaging students in the learning process as active participants rather than passive recipients of information. Constructivist teaching encourages inquiry-based exploration, allowing students to generate their own interpretations and make meaningful connections between concepts and real-world applications (Kussmaul & Pirmann, 2021). In constructivist frameworks, teachers act as facilitators who guide students in problem-solving rather than merely delivering content. Social constructivism furthers the role of collaboration, where students build knowledge collectively through dialogue and shared experiences (Zhu & Atompag, 2023).

Applying the constructivist model in STEAM education provides a dynamic and engaging learning environment that fosters curiosity, motivation, and problem-solving skills. As teachers implement constructivist methodologies, they create structured learning experiences that scaffold new knowledge onto students' prior understandings, making complex concepts more accessible (Serafin et al., 2015). Scaffolding techniques, such as guided inquiry and hands-on experimentation, provide opportunities for students to actively engage with materials and assign personal meaning to their learning (Akpen & Beard, 2016). Active engagement fosters metacognitive awareness, prompting students to reflect on their thought processes and refine their understanding. Furthermore, interlacing technology within constructivist learning environments enhances accessibility and collaboration, reinforcing knowledge construction through interactive, inquiry-based digital tools (Kussmaul & Pirmann, 2021).

In STEAM education, constructivism not only generates excitement but also facilitates deeper learning by incorporating inquiry-driven experiences. Teachers guide students through knowledge-building processes, ensuring that learning remains interactive and student-centered. Fostering cooperative learning environments empowers educators in encouraging students to actively pursue knowledge, make interdisciplinary connections, and apply their understanding to solve real-world challenges (Zhu & Atompag, 2023).

Engaging with prior knowledge in this way activates metacognition, strengthening students' ability to process and retain information (Serafin et al., 2015). Constructivist principles also support differentiated instruction, allowing students to engage with content at their own pace and according to their unique learning styles. Constructivist-based STEAM instruction provides a framework for meaningful and inclusive learning experiences and emphasizes student agency and exploration.

Technology and the Learning Environment

Educators have long incorporated technology into the classroom to enhance student learning. As technology continues to evolve, special education teachers, in particular, must expand their knowledge to reach and support diverse learners effectively. Traditional paper-and-pencil methods have become increasingly obsolete with the widespread integration of digital tools. SmartBoards, ViewSonic displays, interactive gaming platforms, tablets, and Chromebooks have become standard components of modern classrooms. These technological advancements provide opportunities for dynamic, interactive instruction that can accommodate varied learning needs and abilities. In STEAM education, technology is pivotal in fostering inquiry-based, hands-on learning experiences that engage students in creative problem-solving. For students in special education, these tools offer accessibility features such as text-to-speech, voice-to-text, and adaptive interfaces, ensuring participation for all students in learning. Capturing and maintaining student attention is essential for meaningful engagement, and technology serves as a conduit for differentiated, multimodal instruction that supports all learners (Cagiltay et al., 2019).

Constructivist teaching principles interlace with STEAM, special education, personalized learning, and technology integration to support inclusive, inquiry-driven learning. The central hub, "STEAM and Special Education," is an interlaced core that is dynamically supported by surrounding elements for collectively fostering access, engagement, and student agency for all learners (see Figure 1).

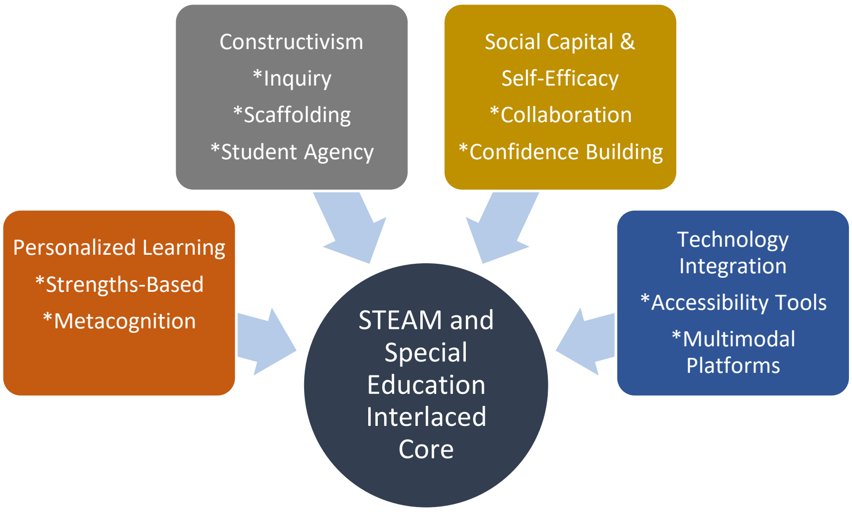

Figure 1. Constructivist STEAM Model for All Learners

Inclusive Learning

STEAM Accessibility for All Learners

Effective teaching requires intentionality in lesson planning and the learning environment, the selection of materials, and the design of student activities. Educators adopting an intentional approach foster access to learning for all students, including those with disabilities (Lu et al., 2020; Wade et al., 2023). Although ensuring accessibility in STEAM education presents challenges, it is essential for creating an inclusive environment that reflects real-world applications (Kryukovs et al., 2023; Spyropoulou & Kameas, 2024).

Science serves as a universal connector among individuals, yet limiting its accessibility to student populations undermines its foundational role in human progress (Boyle et al., 2020; Moon et al., 2012). As educators develop a deeper understanding of their students' academic and developmental needs, they can implement scaffolding strategies that extend knowledge and engagement for all learners (Wade et al., 2023). A variety of opportunities exist within the STEAM classroom to foster inclusion, ensuring that all students, regardless of ability, can meaningfully engage with the curriculum.

Promoting Creativity and Collaboration

While STEAM education cultivates technical competencies, it also enhances critical thinking, engagement, problem-solving, and comprehension. Moreover, STEAM fosters creativity and collaboration, which are skills essential for students to develop a global perspective and successfully navigate an increasingly complex world (Spyropoulou & Kameas, 2024; Wade et al., 2023). However, for STEAM education to be truly inclusive, school districts must ensure that these same skills are intentionally developed among students with disabilities. Access to high-quality STEAM education requires educators to teach these competencies and differentiate instruction based on students' developmental levels. Tailoring STEAM experiences to individual needs enables students to gain the ability to transfer their learning beyond the classroom, applying essential skills across academic, social, and real-world contexts (Kryukovs et al., 2023). Pedagogical approaches and curriculum design play a critical role in equipping teachers with the tools necessary to support diverse learners effectively.

Multisensory Technologies

The National Research Council (NRC) identifies key components of science-based instruction, including hands-on activities, data collection, and data interpretation (Boyle et al., 2020). While these elements are foundational, educators must also interlace evidence-based practices aligned with students' individual learning goals to maximize engagement and achievement (Boyle et al., 2020; Lu et al., 2020). For students with disabilities, STEAM education must incorporate Individualized Education Program (IEP) goals while also leveraging instructional strategies that benefit all learners. Effective teaching practices designed for one group often serve as best practices for all students.

Inclusive instruction necessitates a thoughtful selection of materials and accommodations tailored to the needs of students with disabilities (Mohamed, 2022). The interlacing of assistive technology within STEAM learning environments fosters accessibility, enabling students to engage meaningfully with scientific concepts. In addition, breaking down linguistic and cognitive barriers through multimodal instruction enables educators to create pathways for deeper scientific inquiry (Boyle et al., 2020).

Technology must be both accessible and user-friendly to maximize its impact (Mohamed, 2022). Digital tools such as e-books with text-to-speech capabilities, interactive videos, and touch-responsive applications provide alternative formats for content engagement, bridging learning gaps and fostering comprehension. Learning applications further support students in demonstrating their understanding through varied formats. Instead of relying solely on traditional note-taking, educators can interlace electronic documents, such as Google Docs, to facilitate real-time collaboration.

Additionally, artificial intelligence-powered web platforms equipped with voice recognition technology can transcribe lectures, assisting students who require alternative methods for accessing instructional content (Boyle et al., 2020; Lu et al., 2020). However, implementation depends on teacher preparation and access to necessary resources. Ensuring that educators are equipped with the knowledge, tools, and training to interlace assistive technologies effectively remains a crucial factor in advancing accessibility in STEAM education.

Figure 2 illustrates key design components that collectively support accessible STEAM instruction. These elements, ranging from multisensory technologies and UDL-informed makerspaces to artistic expression and collaborative learning, converge to create inclusive, inquiry-driven educational environments for all learners.

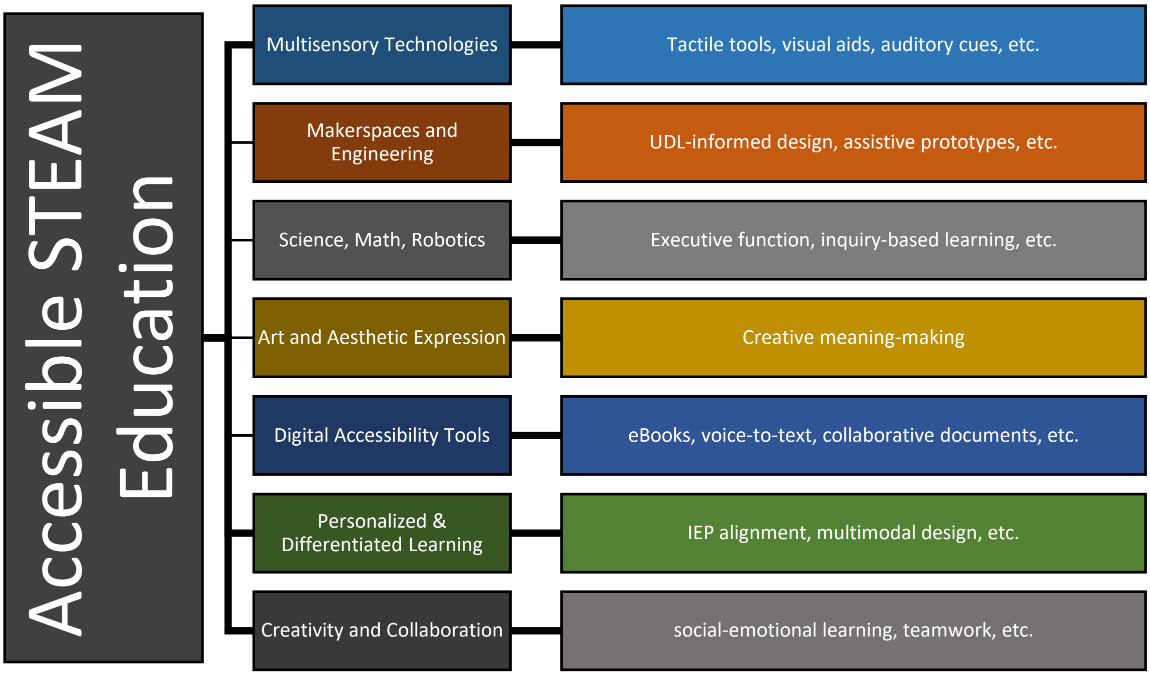

Figure 2. Design Elements of Accessible STEAM Education

Innovation Spaces

Computing, Engineering, and Makerspaces

Computing, engineering, and makerspaces provide a STEAM-driven foundation for fostering creativity, problem-solving, and hands-on engagement for all learners. These innovation spaces interlace physical computing tools, 3D printing, and assistive technologies, offering accessible opportunities for students, particularly those with disabilities, to design and build solutions tailored to real-world challenges (Burgstahler , 2015; Jung & Lee, 2022). Makerspaces promote an inclusive learning environment by enabling students to experiment, prototype, and refine ideas, ensuring that accessibility is embedded into design-thinking processes (Steele et al., 2018). The interlacing of universal design principles within these spaces ensures participation, allowing students with disabilities to engage in engineering, coding, and digital fabrication with tools customized to their needs (Blaser et al., 2018; Li et al., 2015).

The intersection of STEAM education and makerspaces fosters an environment where computational thinking and engineering design merge to develop assistive technologies that enhance accessibility (Jung & Lee, 2022). Encouraging students to create adaptive solutions, such as customized tools or mobility aids using 3D printing and microcontrollers, expands their understanding of engineering while reinforcing the social impact of inclusive innovation (Shatunova et al., 2019). When makerspaces prioritize universal accessibility, they not only provide a space for invention but also empower students to take ownership of the design process, ensuring their work is meaningful and applicable to diverse communities (Steele et al., 2018).

Science, Mathematics, Robotics

STEAM education fosters scientific inquiry, mathematical reasoning, and robotics assimilation, creating dynamic learning experiences that engage all students, including those with disabilities. Multisensory technologies provide hands-on, immersive experiences that enhance students' ability to explore scientific and mathematical concepts through visual, auditory, and kinesthetic engagement (Kim & Park, 2020; Taljaard, 2016). These approaches strengthen problem-solving abilities and executive functions, particularly for students requiring additional cognitive support, by reinforcing concepts through tactile learning and interactive digital tools (Drakatos & Drigas, 2024). Robotics, in particular, serves as a bridge between abstract mathematical principles and tangible real-world applications, enabling students to experiment with coding, mechanics, and computational thinking in ways that support cognitive flexibility and executive function development (Drakatos & Drigas, 2024; Kim & Park, 2020).

Interlacing robotics and mathematics within STEAM frameworks enhances engagement and develops adaptive problem-solving skills for diverse learners. Studies highlight that students with attention-deficit/hyperactivity disorder (ADHD) and other learning differences benefit from structured robotics-based activities, which improve their ability to sequence tasks, regulate impulses, and apply logical reasoning (Drakatos & Drigas, 2024; Park, 2021). Project-based robotics curricula also foster inclusivity by allowing students to collaborate, iterate, and refine their problem-solving approaches, reinforcing both executive functions and social-emotional learning (Davis, 2014; Park, 2021). When mathematics and robotics are embedded within real-world contexts, students develop a deeper conceptual understanding, bridging STEAM disciplines through inquiry, creativity, and computational thinking (Shatunova et al., 2019).

Arts and Aesthetic Learning

Interlacing arts and aesthetic learning within STEAM education fosters creativity, engagement, and deeper conceptual understanding across disciplines. Unlike traditional STEM models that often prioritize analytical reasoning, STEAM's interdisciplinary and transdisciplinary approach promotes both divergent and convergent thinking, allowing students to explore scientific and mathematical concepts through artistic expression (Aguilera & Ortiz-Revilla, 2021). Interlacing bridges logical and creative cognition, helping students develop problem-solving strategies that are both innovative and reflective (Conradty & Bogner, 2020). Artistic practices, such as visualization tools, creative storytelling, and performative representations, support learners by making abstract ideas tangible and personally meaningful (Celepkolu et al., 2021).

Arts-based methodologies in STEAM enhance student motivation and self-efficacy, particularly for learners with disabilities, by offering alternative modes of expression that align with their strengths (Schneps et al., 2010). When students engage in multimodal learning, such as creating digital art to represent scientific data or composing music to demonstrate mathematical patterns, they develop a deeper personal connection to content, reinforcing both retention and comprehension (Conradty & Bogner, 2020; Li et al., 2015). Aesthetic learning environments also cultivate collaboration and dialogue, fostering opportunities for students to co-construct knowledge and reflect on their creative processes (Celepkolu et al., 2021). Embedding artistic inquiry within STEAM education facilitates students not only gaining technical skills but also developing the adaptability and critical thinking necessary for innovation in an ever-evolving world (Aguilera & Ortiz-Revilla, 2021).

Table 2 outlines accessibility strategies aligned with various STEAM domains, highlighting their instructional applications and potential benefits for diverse learners. An accessibility strategies across STEAM domains matrix offers a practical guide for educators seeking to implement inclusive STEAM instruction.

Table 2. Accessibility Strategies Across STEAM Domains

STEAM Domain	Accessibility Strategy	Student Benefit
Multisensory Technologies	Text-to-speech tools, tactile diagrams, interactive simulations	Increases engagement and comprehension for students with disabilities
Makerspaces & Engineering	3D printing, physical computing, adaptive tools	Promotes hands-on learning and innovation for diverse learners
Science & Math	Robotics integration, visual-spatial modeling	Supports executive function, logic, and real-world connections
Arts & Aesthetic Learning	Digital art, storytelling, musical representations	Fosters creativity, emotional expression, and interdisciplinary understanding
Collaborative Tools	Google Docs, AI transcription platforms	Enhances real-time participation and communication
Differentiation & UDL	Scaffolded tasks, IEP alignment, multimodal content delivery	Supports varied developmental levels and learning styles

Curricular Design

One of the primary barriers to STEAM accessibility is teacher capacity. Many educators, whether new to the field or experienced, also have limited training in special education unless they hold a Learning Behavior Specialist (LBS) certification. A lack of preparation impacts instructional planning and the ability to differentiate instruction for students with disabilities (Kryukovs et al., 2023). Differentiated planning challenges stem from the diverse range of disabilities and learning needs, including expressive and receptive language difficulties, sensory processing challenges, and cognitive variability. School districts play a critical role in addressing STEAM and special education growth challenges through mentorship, student-centered coaching, and ongoing professional advancement initiatives.

Establishing a foundation for teacher preparation allows for the development of a cohesive and interdisciplinary curriculum that aligns with Next Generation Science Standards (NGSS) while interlacing mathematics, literacy, and language standards (Boyle et al., 2020). The Universal Design for Learning (UDL) framework ensures accessibility through multiple means of engagement, representation, and expression. Multimodal representations (MMR) and assistive communication devices support students with language barriers, reinforcing access to content (Boyle et al., 2020). Scaffolding instruction through differentiated strategies and accommodations, such as high-contrast printed materials for students with low vision or tactile adaptations for students with sensory sensitivities, allows all learners to engage meaningfully with scientific concepts.

Intentional planning plays a critical role in fostering inclusive learning environments. Accessibility extends beyond physical classroom design to include purposeful interactions and cooperative activities that promote engagement and belonging (Boyle et al., 2020; Mohamed, 2022; Salas-Pilco et al., 2022). Structuring science units with essential questions, vocabulary supports, hands-on activities, and formative and summative assessments provides a clear and inclusive learning pathway. Providing students with choices in how they explore and demonstrate understanding fosters autonomy and engagement. Classroom layout and technology assimilation further enhance accessibility, allowing students to move freely and interact with adaptive digital tools. Flexible seating, unobstructed pathways, and customizable screen settings help create an environment where all students can participate fully in the learning process (Mohamed, 2022).

Differentiating Teaching and Learning

Differentiated instruction is essential in STEAM education to accommodate the diverse learning needs of students, particularly those receiving special education services. Effective differentiation requires intentional planning that aligns instructional strategies with students' cognitive, sensory, and linguistic needs, ensuring access for all learners to STEAM content (Hullender et al., 2016; Li et al., 2015). STEAM education naturally supports differentiation by interlacing multiple disciplines, allowing students to explore concepts through various entry points, such as visual arts, hands-on experimentation, or digital simulations (Hullender et al., 2016; Belland et al., 2017). Inquiry-driven, student-centered learning environments provide flexibility, fostering deeper engagement by adapting content, processes, and outcomes to individual learning profiles.

In inclusive STEAM classrooms, differentiation extends beyond instructional delivery to include adaptive tools and assistive technologies that enable students to demonstrate understanding through multiple modalities (Hullender et al., 2016; Klimaitis & Mullen, 2021). Universal Design for Learning (UDL) frameworks guide this process by encouraging flexible instructional materials and methods that promote accessibility (Boyle et al., 2020). Strategies such as scaffolded inquiry, cooperative learning, and technology-enhanced problem-solving cultivate an inclusive, adaptive learning environment where students of all abilities can engage meaningfully with complex concepts (Belland et al., 2017). Ensuring differentiation within STEAM fosters not only academic success but also enhances students' confidence and problem-solving abilities, preparing them to apply their learning beyond the classroom.

Multiple Pathways for Attaining Knowledge

Differentiated instruction in STEAM education ensures that all learners, including those with disabilities, engage meaningfully with content by adapting instructional methods to accommodate diverse needs. Special education frameworks emphasize differentiated instruction as a way to maximize student success by tailoring content, processes, and learning products to individual strengths, interests, and cognitive profiles (Tomlinson, 2014). A differentiated STEAM classroom approach translates into multiple means of engagement, where students interact with content through hands-on experiences, project-based learning, and interdisciplinary applications that support cognitive flexibility (Davis, 2014; Kryukovs et al., 2023). Effective differentiation considers students' unique abilities, interlacing adaptive strategies such as scaffolded instruction, flexible grouping, and multimodal representations to foster deeper engagement (Klimaitis & Mullen, 2021; Wade et al., 2023).

STEAM education's hands-on, inquiry-based structure aligns naturally with differentiation by allowing students to access content through multiple entry points. Incorporating technology, manipulatives, and problem-solving tasks enables educators to tailor instruction to individual learning needs, particularly for students with disabilities (Mohamed, 2022). Additionally, differentiation in STEAM involves adjusting instructional complexity, ensuring that students engage at appropriate cognitive levels while encouraging the development of problem-solving and creative thinking skills (Spyropoulou & Kameas, 2024). Structuring classroom environments with accessible materials, adaptive tools, and universal design principles supports the diverse range of learners, ensuring that STEAM education remains accessible for all students (Boyle et al., 2020).

Individual Student Needs

When adapted to meet individual student needs, STEAM education fosters an inclusive learning environment where students with specific learning disabilities can develop essential cognitive and problem-solving skills. Students with learning differences often face working memory, executive function, and information processing challenges, which can hinder academic performance (Conradty et al., 2020; Lytra & Drigas, 2021). Interlacing STEAM methodologies with metacognitive strategies enables educators to support students in becoming more self-aware, self-regulated, and adaptable in their learning. Inquiry-based approaches and hands-on, multisensory experiences allow students to engage with content in ways that align with their strengths while addressing areas for growth (Drigas & Mitsea, 2020).

Embedding metacognition into STEAM instruction equips students with the ability to monitor their own cognitive processes, improving their ability to plan, problem-solve, and apply knowledge across disciplines. Providing structured yet flexible learning pathways ensures that students with specific learning needs are accommodated and empowered to take ownership of their educational experiences (Pappas et al., 2018). Through differentiated instruction, assistive technologies, and multimodal learning experiences, STEAM education promotes accessibility, independence, and long-term academic success for all learners.

Universal Design for Learning

Universal Design for Learning (UDL) provides a structured approach to inclusive STEAM education, ensuring that all students, including those with disabilities, have access to content. The UDL framework promotes flexibility in instructional goals, materials, methods, and assessments, allowing educators to proactively address learner variability (Basham & Marino, 2013; Klimaitis & Mullen, 2021). In STEAM classrooms, multiple means of representation, engagement, and expression ensure that students can access, process, and demonstrate learning in ways that align with their individual strengths (CAST, 2011; Conradty et al. 2020). Interlacing multisensory learning tools, assistive technology, and interactive digital resources enhance accessibility for students with diverse cognitive and physical needs (Basham & Marino, 2013).

Effective STEAM instruction rooted in UDL removes barriers to participation while fostering metacognition, creativity, and problem-solving skills. Educators create dynamic and inclusive learning environments by embedding flexible instructional strategies, such as adaptive learning technologies, project-based collaboration, and real-world problem-solving tasks (Basham & Marino, 2013). Intentional design ensures that students not only engage with STEAM concepts but also develop the self-efficacy and skills necessary for lifelong learning.

Figure 3, *Curricular STEAM Design Flow Model for Special Education*, presents a structured progression of instructional design elements that collectively support inclusive learning environments. Moving left and beginning with *Foundational Inputs*, the model emphasizes the importance of teacher capacity, targeted professional learning, and a working understanding of special education needs. Familiarity with the principles of Universal Design for Learning (UDL) and differentiated instruction provides the necessary foundation for planning responsive and accessible STEAM curricula.

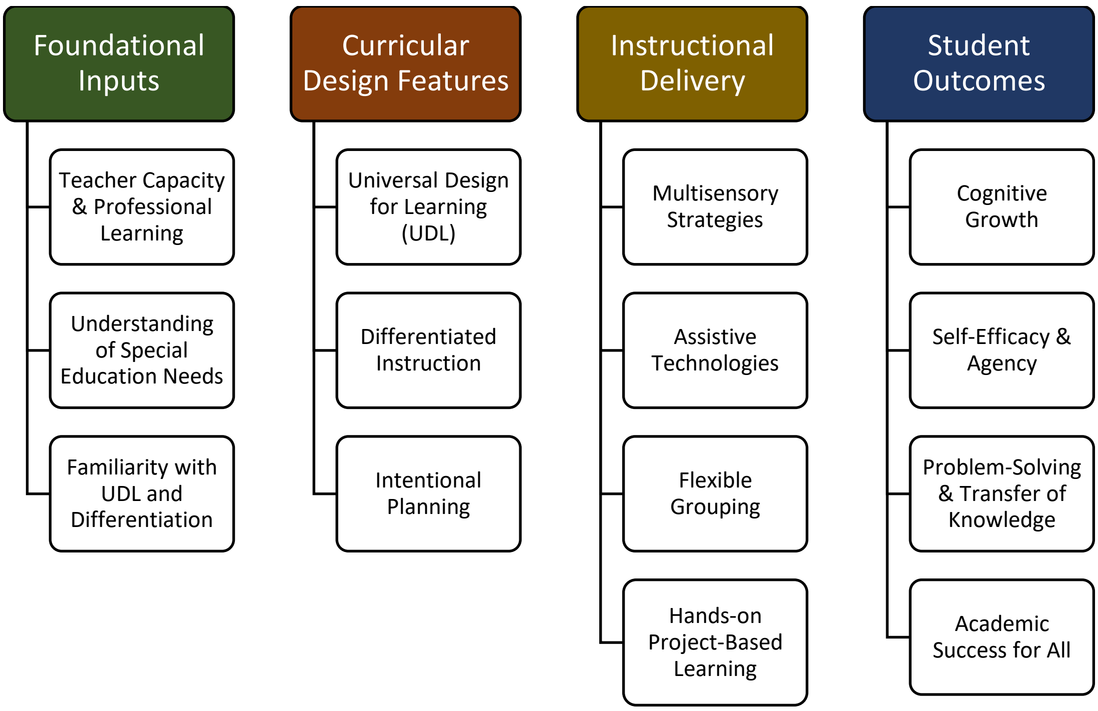

Figure 3. Curricular STEAM Design Flow Model for Special Education

The next level of Figure 3 outlines *Curricular Design Features*, which form the instructional design core. Key elements include the application of UDL through multiple means of engagement, representation, and expression alongside differentiated strategies such as scaffolded inquiry and adaptive content delivery. Intentional planning, including the alignment of instructional practices with NGSS and the integration of flexible classroom design and accessible materials, ensures that all learners have equitable opportunities to participate meaningfully.

The third level, *Instructional Delivery*, reflects the translation of curricular design into classroom practice. Educators implement multisensory strategies, assistive technologies, flexible grouping formats, and hands-on or project-based learning experiences that actively engage diverse learners in inquiry and exploration. The model culminates in *Student Outcomes*, where well-designed and inclusive STEAM instruction fosters cognitive development, self-efficacy, problem-solving skills, and knowledge transfer. Figure 3 illustrates how each level builds upon the previous to create an interconnected system that advances academic success for all students, particularly those receiving special education services.

Technology and Communications

Effective interlacing of technology and communication tools in STEAM education enhances accessibility, engagement, and instructional efficacy for both educators and students. The evolving landscape of educational technology offers opportunities to foster inclusive learning environments, particularly for students with disabilities. However, the success of these innovations depends on teacher capacity, professional development, and strategic implementation. Ensuring that educators possess the skills, confidence, and knowledge to utilize assistive technologies, digital communication tools, and interactive learning platforms is essential for creating access to STEAM content.

Professional erudition is a unifying strategy that combines targeted professional development with ongoing professional learning and supports the continuous growth of educators in STEAM and special education (Dignam, 2025). Enhancing teacher efficacy increases student access to assistive communication devices and personalizing instructional strategies; technology bridges communication gaps and empowers students to participate in the learning process actively. Advancing both teacher professional growth and student-centered technological integration ensures that learning remains dynamic, inclusive, and adaptive to the diverse needs of all learners.

Professional Erudition

Professional Growth for STEAM and Special Education

Strengthening teacher capacity in STEAM and special education remains essential for fostering inclusive, constructivist-based instruction. Although educators express enthusiasm for integrating technology into their instructional strategies, many require additional training to use these tools accurately and effectively. School districts provide a variety of technological resources to enhance student engagement, yet professional development often falls short in building teacher efficacy for sustained and intentional use. According to Bandura (1977), beliefs about personal competence influence behavior, motivation, and performance, emphasizing the need for targeted professional learning that reinforces self-efficacy in instructional practice.

Enhancing teacher efficacy through targeted professional development in STEAM and technology-enhanced instruction leads to increased engagement and more meaningful learning experiences (Conradty & Bogner, 2020).

The reinforcement of instructional success strengthens intrinsic motivation, creating a cycle where confidence and competence drive further professional growth. As teachers develop greater mastery in STEAM pedagogy, their ability to scaffold student learning, facilitate inquiry, and promote creativity improves. The formation of professional learning communities fosters collaboration, shared expertise, and reflective practice, reinforcing critical-thinking skills and instructional innovation while contributing to higher student achievement (Voelkel Jr. & Chrispeels, 2017).

Professional Growth for Capacity Building

Professional development often falls short when delivered by non-affiliated individuals or organizations that lack a deep understanding of school-specific needs and teacher challenges (Gupta & Lee, 2020; Whitworth and Chiu, 2018). Effective professional learning must be contextualized and responsive, ensuring alignment with educators' instructional goals and realities. A study conducted by Gupta and Lee (2020) demonstrated the impact of site-based professional development, where teachers collaborated with a higher education institution to customize training based on their specific instructional needs. A collaborative, site-based approach led to greater mastery of STEAM and special education content delivery, reinforcing the benefits of moving away from generic training models toward targeted, in-situ professional development. Implementing site-based models enhances teacher capacity by providing direct relevance, applicability, and engagement, ultimately improving student achievement.

Targeted Professional Development

A targeted approach to professional growth ensures that STEAM and special education teachers receive individualized support tailored to their instructional needs. Unlike traditional, one-size-fits-all professional development, Targeted Professional Development (TPD) offers personalized learning opportunities based on educator-specific knowledge, instructional practices, and areas for growth (Hirsch et al., 2018). Whitworth and Chiu (2018) highlight that TPD provides structured guidance, mentoring, and direct classroom application, making professional learning more effective and relevant.

Teachers benefit from structured, data-driven training that prioritizes evidence-based practices aligned with STEAM education and special education pedagogy (Simonsen et al., 2020). Ongoing professional learning ensures that educators refine their skills through reflective practice and peer collaboration (Webster-Wright, 2009). Much like site-based professional development, sustained professional learning fosters experiential growth by embedding active participation, real-world application, and iterative improvement. Collaborative learning within professional communities strengthens instructional efficacy, enhances student engagement, and enriches overall teaching effectiveness (Robinson, 2014).

Interlacing Teacher Needs

Professional erudition interlaces targeted professional development with ongoing, site-based professional learning, creating a unifying framework that supports both episodic (singular) and periodic (continuous) professional growth (Dignam, 2024; Dignam et al., 2024). An interlaced, erudite approach ensures that STEAM and special education teachers develop expertise in pedagogy, instructional methodologies, technology integration, and collaborative learning strategies (Dignam, 2024; Shernoff, 2017; So et al., 2021). Professional erudition extends beyond traditional training models, empowering educators to shape their professional learning experiences based on emerging instructional needs and evolving student demands.

Prioritizing ongoing engagement, reflective practice, and targeted skill-building allows professional erudition to serve as a catalyst for instructional innovation and teacher efficacy. Interlacing on-site, targeted professional development with sustained professional learning ensures that educators receive purposeful and relevant training, strengthening their ability to support learners of all backgrounds in STEAM and special education settings (Dignam et al., 2024; Shernoff, 2017).

Table 3 provides an overview of the instructional strategies, frameworks, and professional practices that support accessible and inclusive STEAM education. Each category aligns with curricular design goals to foster equitable access for diverse learners while reinforcing teacher capacity.

Table 3. Curricular Design Framework Supporting STEAM Accessibility and Teacher Capacity

Category	Strategy/Approach	Intended Outcome	Framework or Tool
Differentiated Instruction	Visual, auditory, kinesthetic pathways; scaffolded inquiry	Cognitive flexibility, deeper engagement	UDL, MMR, Assistive Tech
Multiple Pathways	Flexible grouping, multimodal learning, project-based tasks	Access and success for diverse learners	STEAM Design Cycle, PBL
Individual Student Needs	Metacognition, self-regulation, structured support	Academic self-efficacy, independence	Executive Function Strategies, Hands-On Models
Universal Design for Learning	Flexible materials, varied assessments, inclusive classroom setup	Barrier-free access to instruction	UDL Framework
Technology & Communication	Assistive devices, adaptive software, collaboration tools	Accessible expression and classroom participation	Co-Writer, Talk-to-Text, Interactive Tools
Professional Erudition	Targeted PD, site-based mentoring, reflective learning	Increased teacher efficacy, sustainable change	TPD, Site-Based PD, PLCs

Personalizing Teaching and Learning

Assisted Technologies

Ensuring that all students can communicate effectively remains essential for fostering an inclusive, cooperative learning environment. Assistive technologies such as Co-Writer, talk-to-text, intensive communication devices, amplifiers, Big Mack, virtual reality headsets, and See Sound Live provide students with diverse means of expressing and processing information. These tools remove communication barriers, enabling students to engage with STEAM subjects through adapted learning strategies that accommodate varied needs.

Technology-driven communication tools enhance collaboration, engagement, and accessibility in STEAM education. Students benefit from interactive, multimodal learning experiences, ensuring that content is not only accessible but also meaningful and individualized. Digital learning platforms, speech-to-text applications, and interactive simulations support receptive and expressive communication, providing students with alternative ways to participate in academic discussions. Game-based learning and technology-enhanced instruction further encourage exploration, reinforcing student agency and engagement (Best et al., 2019; Costello, 2022; Moon et al., 2012).

Improving Student Participation

Individualized instruction fosters higher levels of student participation, particularly when educators integrate constructivist approaches, assistive technologies, and inclusive instructional strategies. Providing students with personalized learning experiences strengthens intrinsic motivation, allowing them to connect prior knowledge to new explorations. When learning is collaborative, inquiry-based, and differentiated, students gain a greater sense of ownership and agency, reinforcing both engagement and academic self-efficacy.

Creativity in STEAM education further enhances participation as students develop knowledge through real-world applications and hands-on experiences. Exploratory instruction, where students engage in open-ended problem-solving, fosters intellectual curiosity and deeper cognitive engagement. Meaningful, student-centered learning environments that interlace technology, inquiry, and interdisciplinary collaboration result in increased student satisfaction and motivation (Conradty & Bogner, 2020; Castelo, 2020; Akpan & Beard, 2016).

Digital Fabrication and Design

Introducing Concepts

Embedding STEAM education into the curriculum from the earliest stages of a student's academic experience builds a strong foundation in scientific inquiry and problem-solving. Early exposure ensures that students develop the skills necessary to navigate a science-driven global society while preparing for 21st-century careers (Kinnula et al., 2021; Kryukovs et al., 2023). One strategy that strengthens this foundation is digital fabrication, a process that leverages technology for product design, development, and prototype creation. While digital fabrication applies to multiple fields, successful implementation in education requires institutional support and buy-in from school districts. Teachers and administrators play a pivotal role in guiding and sustaining these initiatives, ensuring that students receive authentic, hands-on learning experiences (Kinnula et al., 2021).

Through digital fabrication, students engage with engineering, computer science, and artistic design, reflecting the interdisciplinary nature of STEAM education (Georgiev & Nanjappan, 2023; Kinnula et al., 2021). The growing emphasis on design and engineering education has led to increased interlacing of fabrication tools such as 3D printers in classrooms. These tools allow students to transform abstract concepts into tangible creations, reinforcing spatial reasoning, problem-solving, and critical thinking skills. Students develop a deeper understanding of design processes, iteration, and real-world applications by turning ideas into physical models.

Child-Computer interactions

Digital technologies perform a pivotal role in fostering engagement and cognitive development for all learners, particularly those with diverse needs (Israel et al., 2013). Child-computer interactions within STEAM education emphasize participatory design, allowing students to navigate digital platforms that support inquiry, creativity, and problem-solving (Israel et al., 2013; Pari-Larico et al., 2020; Vasalou et al., 2021). Developmentally diverse children, including those with dyslexia and cerebral palsy, benefit from interactive learning environments that interlace assistive technologies, which enhance both communication and learning (Erdem, 2017). These tools provide students with alternative means to engage with content, facilitating both receptive and expressive learning.

Interlacing digital interactions into STEAM education requires intentional design that prioritizes accessibility. Studies highlight that participatory design frameworks empower students by incorporating their perspectives into the development of digital tools, ensuring usability and engagement (Tomar et al., 2020; Vasalou et al., 2021). Assistive technologies such as voice recognition, adaptive touch interfaces, and symbol-based communication systems enable students with special needs to actively participate in computational learning experiences (Aronin & Floyd, 2013). Educators create inclusive learning spaces where all students, regardless of ability, can collaborate, explore, and innovate by embedding child-centered digital interactions within STEAM curricula.

Gameplay and Engaging All Learners

Game-based learning within STEAM education provides an immersive and dynamic platform for engaging all learners, particularly students with disabilities. Interactive and adaptive games offer structured and exploratory experiences that foster cognitive development, executive function, and problem-solving abilities (Pari-Larico et al., 2020; Tlili et al., 2022; Tomar et al., 2020). Incorporating tangible robotics, eye-tracking technology, and adaptive feedback systems allows students to develop critical thinking and logic while engaging in meaningful, interactive play (Olsen et al., 2022; Park, 2022). Technologies such as these create opportunities for diverse learners to build memory, attention, and problem-solving skills in ways that cater to their individual needs.

Serious games designed for educational purposes extend beyond entertainment, providing structured pathways for skill acquisition, particularly in literacy, numeracy, and computational thinking (Cano et al., 2016). Research highlights the value of both free-form and structured gameplay, with open-ended digital environments allowing creativity and self-directed learning. In contrast, more structured game mechanics reinforce goal-oriented tasks (Kirginas et al., 2021). Whether through robotics-based activities, gamified learning experiences, or interactive digital tools, game-based learning environments cultivate engagement by tailoring content to individual student needs, supporting accessibility, and enhancing learning outcomes in STEAM education.

Learning Apps

Digital learning applications provide dynamic, interactive environments that support individualized instruction, particularly for students with diverse learning needs. Mobile and tablet-based applications offer multimodal engagement, allowing students to access STEAM content through visual, auditory, and tactile interactions (Schneps et al., 2010; Tomar et al., 2020). Itinerant platforms interlace adaptive learning algorithms that personalize instruction based on student responses, ensuring differentiated support that aligns with individual learning styles and cognitive processing needs (de Albuquerque Wheler et al., 2021).

Educational apps designed with user-friendly interfaces enhance accessibility for students with disabilities, reducing cognitive load and increasing engagement with STEAM curricula (de Albuquerque Wheler et al., 2021; Pari-Larico et al., 2020). Features such as voice-to-text, text-to-speech, and interactive simulations create meaningful opportunities for students to explore concepts beyond traditional instruction (Park, 2022; Schneps et al., 2010). Additionally, gamification elements, including achievement-based progressions and interactive challenges, foster motivation and perseverance, essential qualities for STEAM-based inquiry (Albuquerque Wheler et al., 2021). When thoughtfully designed, digital applications serve as powerful tools for reinforcing STEAM education, bridging gaps in accessibility, and fostering learning experiences for all students.

Conceptualization and Actualization

The process of conceptualization and actualization in STEAM education involves the transformation of abstract ideas into tangible projects through digital fabrication, assistive technologies, and interactive tools. For students with special education needs, this process requires intentional design approaches that support diverse cognitive and physical abilities. Assistive technologies, such as adaptive controllers and digital modeling software, enable students to engage in iterative design processes, fostering both creativity and problem-solving (Erdem, 2017; Park, 2022). The emphasis on hands-on learning through structured and open-ended activities allows students to refine their understanding by interacting with digital interfaces that adapt to their individual learning profiles (Aronin & Floyd, 2013).

Encouraging students to transition from conceptualization to actualization requires a balance between structured guidance and open-ended exploration. Research on free-form and structured gameplay demonstrates that students exhibit heightened engagement and learning retention when they can explore digital tools with autonomy while also receiving scaffolded support for skill development (Kirginas et al., 2021). Designing digital learning environments that interlace both structured guidance and student-driven exploration fosters cognitive flexibility, social interaction, and self-directed learning. A structured approach enhances the accessibility of STEAM education, ensuring that students with diverse learning needs can translate their ideas into meaningful, applied outcomes.

Digital Citizenship

As technology becomes an integral part of education, digital citizenship must be introduced early in a student's academic career. The International Society for Technology in Education (ISTE) Standards for Teachers outline key competencies, including global awareness, ethical technology use, and copyright considerations (Armfield & Blocher, 2019). However, ensuring that students with disabilities develop digital citizenship skills requires intentional instructional design. Just as modifications and accommodations support learning in other content areas, digital citizenship lessons must be adapted to meet the needs of all learners while maintaining alignment with established standards. Teachers must consider how technology can both include and unintentionally exclude students, emphasizing accessibility in lesson planning (Armfield & Blocher, 2019).

Embedding digital citizenship within STEAM curricula requires teacher proficiency in both the standards and their application. Educators must ensure that students with disabilities not only meet IEP goals but also gain access to digital tools that foster participation in academic, social, and professional digital spaces (Armfield & Blocher, 2019). Access to assistive technologies and adaptive learning platforms helps bridge the digital divide, yet socioeconomic disparities and district resources can impact the level of exposure students receive. Technology integration depends on purposeful instructional planning, particularly for students with disabilities, ensuring that all learners develop the skills needed to navigate, engage, and contribute in an increasingly digital world (Armfield & Blocher, 2019). Table 4 illustrates digital strategies interlaced within STEAM education, highlighting the tools, learning benefits, and accessibility features that support diverse learners across developmental and instructional contexts.

Table 4. Digital Tools and Strategies Supporting STEAM Learning for Diverse Learners

STEAM Strategy	Tool/Approach	Learning Benefit	Accessibility Feature
Digital Fabrication	3D printers, modeling software	Enhances design thinking, spatial reasoning	Tangible outputs for abstract concepts
Child-Computer Interaction	Adaptive interfaces, symbol-based systems	Encourages expressive/receptive learning	Touch input, voice recognition, assistive UI
Game-Based Learning	Eye-tracking tech, robotics, serious games	Improves problem-solving and executive function	Adaptive feedback, multimodal game mechanics
Learning Apps	Mobile/tablet-based interactive apps	Supports personalized instruction, motivation	Text-to-speech, gamification, low cognitive load UI
Conceptualization to Actualization	Open-ended and structured digital design	Fosters creativity, autonomy, cognitive flexibility	Scaffolded digital environments, accessible iteration tools
Digital Fabrication	3D printers, modeling software	Enhances design thinking, spatial reasoning	Tangible outputs for abstract concepts

Conclusion

Interlacing STEAM education and special education fosters an inclusive and dynamic learning environment where students of all abilities can engage meaningfully with content. STEAM creates opportunities for students to develop problem-solving, creativity, and critical-thinking skills through inquiry-driven learning by integrating interdisciplinary and transdisciplinary approaches. The inclusion of digital fabrication, assistive technologies, and game-based learning ensures that instructional strategies remain accessible, flexible, and responsive to the diverse needs of students. Furthermore, UDL and differentiated instruction provide essential frameworks for ensuring that all students, including those with disabilities, can access and engage with STEAM curricula.

Ensuring access to STEAM education requires intentional curricular planning, teacher professional development, and the thoughtful integration of digital tools. When educators are empowered with the skills and knowledge to implement adaptive learning technologies, personalized instruction, and collaborative learning environments, students are better positioned for academic success and real-world application of their knowledge. As STEAM education continues to evolve, the emphasis must remain on fostering inclusive, inquiry-driven, and technology-enhanced experiences that prepare all learners to thrive in a rapidly changing world.

Recommendations

To enhance the effectiveness of STEAM education for all learners, schools should adopt Individualized Learning Plans (ILPs) for all students, not just those with disabilities. In addition, ILPs provide structured, student-centered learning pathways that consider individual strengths, interests, and learning needs, ensuring that all students receive personalized support and enrichment opportunities within STEAM curricula. Implementing ILPs fosters greater engagement, self-efficacy, and academic success, particularly when integrated with UDL and differentiated instruction.

Additionally, paraprofessionals should be included in professional erudition for targeted growth to ensure they can effectively support students within STEAM and special education settings. Providing paraprofessionals with training in assistive technologies, inquiry-based learning strategies, and inclusive instructional practices strengthens their ability to facilitate student engagement and scaffold learning experiences. Schools must also prioritize family engagement by keeping parents informed about STEAM initiatives, technological tools, and instructional approaches that support their children’s learning. Finally, fostering a growth mindset among administrators and teachers is essential for sustaining comprehensive, innovative, and adaptive STEAM education. Leadership must advocate for institutional support, resource allocation, and continuous professional growth, ensuring that STEAM and special education remain interlaced in fostering student learning opportunities.

References

Aguilera, D., & Ortiz-Revilla, J. (2021). STEM vs. STEAM education and student creativity: A systematic literature review. *Education Sciences*, *11*(7), 331. https://doi.org/10.3390/educsci11070331

Akpan, J. P., & Beard, L. A. (2016). Using constructivist teaching strategies to enhance academic outcomes of students with special needs. *Universal Journal of Educational Research*, *4*(2), 392-398. https://doi.org/10.13189/ujer.2016.040211

Allina, B. (2018). The development of STEAM educational policy to promote student creativity and social empowerment. *Arts Education Policy Review*, *119*(2), 77-87. https://doi.org/10.1080/10632913.2017.1296392

Armfield, S. W. J. & Blocher, J. M. (2019). Global digital citizenship: Providing context. *TechTrends*, 63(4), 470-476. https://doi.org/10.1007/s11528-019-00381-7

Aronin, S., & Floyd, K. K. (2013). Using an iPad in inclusive preschool classrooms to introduce STEM concepts. *Teaching Exceptional Children*, *45*(4), 34-39. https://doi.org/10.1177/004005991304500404

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review*, *84*(2), 191–215. https://doi.org/10.1037/0033-295X.84.2.191

Barth, M., Jiménez-Aceituno, A., Lam, D. P., Bürgener, L., & Lang, D. J. (2023). Transdisciplinary learning as a key leverage for sustainability transformations. *Current Opinion in Environmental Sustainability*, *64*, 101361. https://doi.org/10.1016/j.cosust.2023.101361

Basham, J. D., Israel, M., & Maynard, K. (2010). An ecological model of STEM education: Operationalizing STEM for all. *Journal of Special Education Technology*, *25*(3), 9-19. https://doi.org/10.1177/016264341002500303

Basham, J. D., & Marino, M. T. (2013). Understanding STEM education and supporting students through universal design for learning. *Teaching exceptional children*, *45*(4), 8-15.

Belland, B. R., Walker, A. E., Kim, N. J., & Lefler, M. (2017). *Scaffolding during problem-based learning: A meta-analysis. Educational Psychologist*, *52*(2), 104-123. https://doi.org/10.3102/0034654316670999

Best, N. M., Best, R. R., & Dickter, L. C. (2019). STEAM programming as a pathway to foster positive academic self-efficacy and positive self-concept. *Journal of Research in STEM Education*, *5*(2), 100-118. https://doi.org/10.51355/jstem.2019.54

Bloomquist, C. D., & Georges, L. (2022). Interdisciplinary leadership: A leadership development model for scholar-practitioners. *Journal of Leadership Education*, *21*(4). https://doi.org/10.12806/V21/I4/A4

Boyle, S., Rizzo, K. L., & Taylor, J. C. (2020). Reducing language barriers in science for students with special educational needs. *Asia-Pacific science education*, *6*(2), 364-387. https://doi.org/10.1163/23641177-BJA10006

Burgstahler, S. (2015). Making a makerspace? Guidelines for accessibility and universal design. *DO-IT (Disabilities, Opportunities, Internetworking, and Technology) Center, University of Washington*. https://www.washington.edu/doit/making-makerspace-guidelines-accessibility-and-universal-design

Cagıltay, K., Cakır, H., Karasu, N., Islım, O. F., & Cıcek, F. (2019). Use of educational technology in special education: Perceptions of teachers. *Participatory Educational Research*, *6*(2), 189-205. https://doi.org/10.17275/per.19.21.6.2

Cano, S., Collazos, C. A., Manresa-Yee, C., & Peñeñory, V. (2016, September). Principles of design for serious games to teaching of literacy for children with hearing disabilities. In *Proceedings of the XVII International Conference on Human Computer Interaction* (1-2).

https://doi.org/10.1145/2998626.2998650

CAST. (2011). *Universal Design for Learning Guidelines version 2.0*. Wakefield, MA: Author.

Castelo, M. (2020). Assistive technology in the classroom empowers students with disabilities. EsTech Focus on K-12, March. https://edtechmagazine.com/k12/article/2020/03/using-assistive-technology-empower-students-disabilities-perfcon

Celepkolu, M., Wiggins, J. B., Galdo, A. C., & Boyer, K. E. (2021). Designing a visualization tool for children to reflect on their collaborative dialogue. *International journal of child-computer interaction*, *27*, 100232. https://doi.org/10.1016/j.ijcci.2020.100232

Clark, B., & Button, C. (2011). Sustainability transdisciplinary education model: Interface of arts, science, and community (STEM). *International Journal of Sustainability in Higher Education*, *12*(1), 41–54. https://doi.org/10.1108/14676371111098294

Conradty, C., Sotiriou, S. A., & Bogner, F. X. (2020). How creativity in STEAM modules intervenes with self-efficacy and motivation. *Education Sciences, 10*(3), 1–15. https://doi.org/10.3390/educsci10030070

Conradty, C., & Bogner, F. X. (2020). STEAM teaching professional development works: Effects on students' creativity and motivation. *Smart Learning Environments*, *7*, 1-20. https://doi.org/10.1186/s40561-020-00132-9

Costello, R. (2022). Future directions of gamification in education. In *Research Anthology on Developments in Gamification and Game-Based Learning* (pp. 123–145). https://doi.org/10.4018/978-1-7998-2079-6.ch013

Davis, K. E. B. (2014). The need for STEM education in special education curriculum and instruction. *STEM Education: Strategies for teaching learners with special needs*, 1-20.

de Albuquerque Wheler, A. P., Kelner, J., Hung, P. C., de Souza Jeronimo, B., Junior, R. D. S. R., & Araújo, A. F. R. (2021). Toy user interface design—tools for child–computer interaction. *International Journal of Child-Computer Interaction*, *30*, 100307. https://doi.org/10.1016/j.ijcci.2021.100307

Dignam, C. (2024). Harmonies on the String: Exploring the Synergy of Music and STEM. *International Journal of Technology in Education and Science (IJTES), 8*(3), 491-521. https://doi.org/10.46328/ijtes.571

Dignam, C. (2025). Makerspace and the 5 C's of learning: Constructing, collaborating, communicating, critically-thinking, and creatively-thinking. *International Journal of Studies in Education and Science (IJSES), 6*(1), 104-127. https://doi.org/10.46328/ijses.135

Dignam C., Pennington, L. K., & Daifallah, A. (2024). Beyond the acronym: Interconnections of STEAM, the humanities, and digital citizenship. *International Journal on Social and Education Sciences*, *6*(3), 452-480. https://doi.org/10.46328/ijonses.686

Drakatos, N., & Drigas, A. (2024). The impact of STEAM education using robotics on the executive function of typical and ADHD students along with developmental exploration. *Brazilian Journal of Science, 3(2)*, 113-122. https://doi.org/10.14295/bjs.v3i2.467

Drigas, A. S., & Mitsea, E. (2020). The 8 pillars of metacognition. *International Journal of Emerging Technologies in Learning (iJET), 15*(21), 162–178. https://doi.org/10.3991/ijet.v15i21.14907

Erdem, R. (2017). Students with special educational needs and assistive technologies: A literature review. *Turkish Online Journal of Educational Technology-TOJET, 16*(1), 128-146.

Georgiev, G. V. & Nanjappan, V. (2023). Sustainability considerations in digital fabrication design education.

Sustainability, *15*(2), 1-15. https://doi.org/10.3390/su15021519

Gupta, A., & Lee, G.-L. (2020). The effects of a site-based teacher professional development program on student learning. *International Electronic Journal of Elementary Education, 12*(5), 417–428. https://doi.org/10.26822/iejee.2020562132

Henriksen, D. (2017). Creating STEAM with design thinking: Beyond STEM and arts integration. *The STEAM Journal*, *3*(1), 11. https://doi.org/10.5642/steam.20170301.11

Hirsch, S. E., Ely, E., Lloyd, J. W., & Isley, D. (2018). Targeted professional development: A data-driven approach to identifying educators' needs. *School-University Partnerships, 11*(2), 84–91.

Hullender, R., Hoffman, H., & Cunningham, J. (2016). STEAM: Creating an environment of inclusion and innovation.

Israel, M., Marino, M. T., Basham, J. D., & Spivak, W. (2013). Fifth graders as app designers: How diverse learners conceptualize educational apps. *Journal of research on technology in education*, *46*(1), 53-https://doi.org/80. 10.1080/15391523.2013.10782613

Jia, Y., Zhou, B., & Zheng, X. (2021). A curriculum integrating STEAM and maker education promotes pupils' learning motivation, self-efficacy, and interdisciplinary knowledge acquisition. *Frontiers in Psychology*, *12*, Article 725525. https://doi.org/10.3389/fpsyg.2021.725525

Jung, Y. C., & Lee, K. T. (2022). A STEAM experience activity task: Making and experiencing goods for the disabled with physical computing tools and 3D printing technology. *Brain, Digital, & Learning, 12*(4), 675-692. https://doi.org/10.31216/BDL.20220042

Kim, S. H., & Park, H. W. (2020). Development and application of a STEAM education program using 3D printing technology for high school students. *Journal of Engineering Education Research*, *23*(3), 197-204. https://doi.org/10.18108/jeer.2020.23.3.197

Kinnula, M., Iivari, N., & Fails, J. A. (2021). Children's learning in focus: Creating value through diversity and transdisciplinary work in design, digital fabrication, and making with children. *International Journal of Child-Computer Interaction*, *28*, 100246. https://doi.org/10.1016/j.ijcci.2020.100246

Kirginas, S., Psaltis, A., Gouscos, D., & Mourlas, C. (2021). Studying children's experience during free-form and formally structured gameplay. *International Journal of Child-Computer Interaction*, *28*, 100248. https://doi.org/10.1016/j.ijcci.2021.100248

Klimaitis, C. C., & Mullen, C. A. (2021). Including K-12 Students with Disabilities in STEM Education and Planning for Inclusion. *Educational Planning*, *28*(2), 27-43.

Kryukovs, N. I., Rastorgueva, B. E., Popova, E. O., Zakharova, V. L., Aytuganova, J. I., & Bikbulatova, G. I. (2023). Examining the implementations related to teaching science to students with disabilities. Eurasia Journal of Mathematics, Science and Technology Education. 19(8), 1-16. https://doi.org/10.29333/ejmste/13427

Kussmaul, C., & Pirmann, T. (2021, April). Guided inquiry learning with technology: Investigations to support social constructivism. *In CSEDU (1)* (pp. 483-490). https://doi.org/10.5220/0010458104830490

Li, S., Ernst, J. V., & Williams, T. O. (2015). Supporting students with disabilities and limited English proficiency: STEM educator professional development participation and perceived utility. *International Journal of STEM Education*, *2*(1), 1-10. https://doi.org/10.1186/s40594-015-0033-9

Liao, C. (2016). From interdisciplinary to transdisciplinary: An arts-integrated approach to STEAM education.

Art Education, *69*(6), 44–49. https://doi.org/10.1080/00043125.2016.1224873

Lu, S. Y., Wu, C. L., & Huang, Y. M. (2022). Evaluation of disabled STEAM-students' education learning outcomes and creativity under the UN sustainable development goal: project-based learning oriented STEAM curriculum with micro: bit. *Sustainability*, *14*(2), 679. https://doi.org/10.3390/su14020679

Lytra, N., & Drigas, A. (2021). STEAM education-metacognition–Specific Learning Disabilities. *Scientific Electronic Archives*, *14*(10). https://doi.org/10.36560/141020211442

Mohamed, E. F. (2022). Inclusion of STEAM innovation spaces: A critical issue for learners with Disabilities. *Nafath*, *7(21).* https://doi.org/10.54455/mcn.21.03

Moon, N. W., Todd, R. L., Morton, D. L., & Ivey, E. (2012). Accommodating students with disabilities in science, technology, engineering, and mathematics (STEM). *Atlanta, GA: Center for Assistive Technology and Environmental Access, Georgia Institute of Technology*, *8*(21).

Olsen, J. K., Ozgur, A. G., Sharma, K., & Johal, W. (2022). Leveraging eye tracking to understand children's attention during game-based, tangible robotics activities. *International Journal of Child-Computer Interaction*, *31*, 100447. https://doi.org/10.1016/j.ijcci.2021.100447

Pappas, M. A., Drigas, A. S., & Polychroni, F. (2018). An Eight-Layer Model for Mathematical Cognition. *International Journal of Emerging Technologies in Learning (iJET)*. **https://doi.org/10.3991/ijet.v13i10.8633**

Pari-Larico, J. E. T. S., Llerena-Urday, B., Carpio, A. F. D., & Rosas-Paredes, K. (2020). Interactive toy to strengthen the memory attention and logic of primary education students using sphero Arduino and NeuroSky MindWave EEG. In *Proc. 6th Iberoamerican Conf. Comput. Hum. Interact.* (Vol. 2747, pp. 245-254).

Park, Y. (2022). Analysis of Teachers' Questions in the STEAM Class for Students with Intellectual Disabilities. *Journal of Curriculum and Teaching*, *11*(5), 205-214. https://doi.org/10.5430/jct.v11n5p205

Park, Y. (2021). The perception of special education teachers for implementing STEAM education for students with intellectual disabilities. *Turkish Journal of Computer and Mathematics Education, 12(10)*, 925-932. https://doi.org/10.18173/2354-1075.2022-0125

Puccia, E., Martin, J. P., Smith, C. A., Kersaint, G., Campbell-Montalvo, R., Wao, H., ... & MacDonald, G. (2021). The influence of expressive and instrumental social capital from parents on women and underrepresented minority students' declaration and persistence in engineering majors. *International Journal of STEM Education*, *8*, 1-15. https://doi.org/10.1186/s40594-021-00277-0

Rabin, J. M., Burgasser, A., Bussey, T. J., Eggers, J., Lo, S. M., Seethaler, S., ... & Weizman, H. (2021). Interdisciplinary conversations in STEM education: Can faculty understand each other better than their students do?. *International Journal of STEM Education*, *8*, 1-10. https://doi.org/10.1186/s40594-020-00266-9

Robinson, V. M. J. (2014). Transforming professional development to professional learning. *Educational Leadership*, *71*(8), 10–18.

Salas-Pilco, S. Z. (2020). The impact of AI and robotics on physical, social-emotional and intellectual learning outcomes: An integrated analytical framework. *British Journal of Educational Technology*, *51*(5), 1808-1825. https://doi.org/10.1111/bjet.12984

Saw, G. K. (2020). Leveraging social capital to broaden participation in STEM. *Policy Insights from the*

Behavioral and Brain Sciences, *7*(1), 35–43. https://doi.org/10.1177/2372732219895997

Schneps, M. H., O'Keeffe, J. K., Heffner-Wong, A., & Sonnert, G. (2010). Using technology to support STEM reading. *Journal of Special Education Technology, 25*(3), 21-32. https://doi.org/10.1177/016264341002500304

Serafín, Č., Dostál, J., & Havelka, M. (2015). Inquiry-based instruction in the context of constructivism. *Procedia-Social and Behavioral Sciences*, *186*, 592-599. https://doi.org/10.1016/j.sbspro.2015.04.050

Shatunova, O., Anisimova, T., Sabirova, F., & Kalimullina, O. (2019). STEAM as an innovative educational technology. *Journal of Social Studies Education Research*, 10(2), 131–144

Shernoff, D. J., Sinha, S., Bressler, D. M., & Ginsburg, L. (2017). Assessing teacher education and professional development needs for the implementation of interlaced approaches to STEM education. *International Journal of STEM Education*, *4*, 1-16. https://doi.org/10.1186/s40594-017-0068-1

Simonsen, B., Freeman, J., Dooley, K., Maddock, E., Kern, L., & Myers, D. (2018). Using data to support teachers' implementation of empirically supported classroom practices. *Journal of Positive Behavior Interventions*, *20*(1), 47–60. https://doi.org/10.1353/etc.2019.0013

So, W. W. M., He, Q., Cheng, I. N. Y., Lee, T. T. H., & Li, W. C. (2021). Teachers' professional development with peer coaching to support students with intellectual disabilities in STEM learning. *Educational Technology & Society*, *24*(4), 86-98. https://www.jstor.org/stable/48629247

Spyropoulou, N. & Kameas, A. (2024). Augmenting the impact of STEAM education by developing a competence framework for STEAM educators for effective teaching and learning. Education Science, 14(1), 1-30. https://doi.org/10.3390/educsci14010025

Steele, K. M., Blaser, B., & Cakmak, M. (2018). Accessible making: Designing makerspaces for accessibility. *International Journal of Designs for Learning*, 9(1), 114–121. https://doi.org/10.14434/ijdl.v9i1.22648

Taljaard, J. (2016). A review of multi-sensory technologies in a science, technology, engineering, arts and mathematics (STEAM) classroom. *Journal of learning Design*, *9*(2), 46-55.

Tlili, A., Denden, M., & Duan, A. (2022). Game-based learning for learners with disabilities—What is next? A systematic literature review from the activity theory perspective. *Frontiers in Education*, *7*, Article 793998. https://doi.org/10.3389/fpsyg.2021.814691

Tomar, G., & Garg, V. (2020). Making steam accessible for inclusive classrooms. *Global Journal of Enterprise Information System*, *12*(4), 94-101.

Tomlinson, C. A. (2014). *The differentiated classroom: Responding to the needs of all learners* (2nd ed.). ASCD.

Tytler, R. (2020). STEM education for the twenty-first century. Integrated approaches to STEM education: An international perspective, 21-43. https://doi.org/10.1007/978-3-030-52229-2_3

Vasalou, A., Ibrahim, S., Clarke, M., & Griffiths, Y. (2021). On power and participation: Reflections from design with developmentally diverse children. *International journal of child-computer interaction*, *27*, 100241. https://doi.org/10.1016/j.ijcci.2020.100241

Voelkel Jr., R. & Chrispeels, J. (2017): Understanding the link between professional learning communities and teacher collective efficacy, School Effectiveness and School Improvement To link to this article: http://dx.doi.org/10.1080/09243453.2017.1299015

Wade, C. B., Koc, M., Searcy, A., Coogle, C., & Walter, H. (2023). STEAM activities in the inclusive classroom: Intentional planning and practice. *Education Sciences*, *13*(11), 1161.

https://doi.org/10.3390/educsci13111161

Webster-Wright, A. (2009). Reframing professional development through understanding authentic professional learning. *Review of Educational Research*, *79*(2), 702–739. https://doi.org/10.3102/0034654308330970

Whitworth, B. A., & Chiu, J. L. (2015). Professional development and teacher change: The missing leadership link. *Journal of Science Teacher Education*, *26*(2), 121–137. Zayyad, M. (2019). STEAM education for students with specific learning disorders. *Research highlights in education and science*, 31-42. https://doi.org/10.1007/s10972-014-9411-2

Zhu, L., & Atompag, S. M. (2023). The application of the constructivism theory in enhancing classroom teaching. *Journal of Contemporary Educational Research*, *7*(12), 209-213. https://doi.org/10.26689/jcer.v7i12.5792

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