Interdisciplinary Education

Literature Review and Landscape Analysis

Prepared for
Lucas Education Research

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Contents

Part II: Landscape Analysis II-1

Part I: Literature Review

1. Introduction

This literature review is the first of two parts of the Interdisciplinary Education Literature Review and Landscape Analysis conducted by RTI International for Lucas Education Research (LER). The intended overall outcomes of the project are to provide background research to LER for the development of

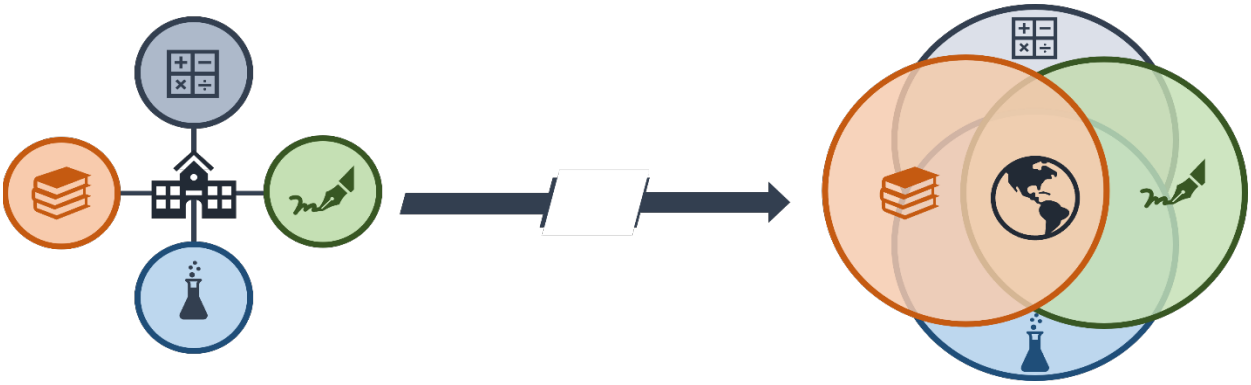
- a working definition of interdisciplinary education to guide LER's work;
- a foundational document that can be used by LER staff, leadership, and potential grantees in the early stages of this work;
- a synthesis of literature and landscape analysis to reveal gaps, opportunities, and implementation barriers for future directions of LER grantmaking.

In Part I, after a brief introduction of the history of interdisciplinary education and the research questions and methods (Section 1), the literature review will proceed with four sections: an overview of existing definitions of interdisciplinary education, including an analysis of overlap and distinctions with related educational approaches (Section 2); contexts in which interdisciplinary education is being implemented (Section 3); existing evidence for effects of interdisciplinary education on student cognitive and noncognitive outcomes (Section 4); and current gaps in the research literature (Section 5).

1.1 Background

Disciplines, or school subjects, have been the dominant educational structure throughout the 20th century and continue to dominate through the present day (Klein, 2006). This departmentalized approach to learning is convenient for the institutional and logistical demands of K–12 schooling, including establishing clear subject area learning standards, testing students as part of accountability mandates, creating school schedules, and developing and enforcing teacher training and licensure requirements. However, disciplinary distinctions are artificially constructed and can impede students' holistic understanding of the world. As early as the 1900s, John Dewey argued that integrated learning was far more natural to students than discipline-based learning and that arbitrarily separating content areas in the school curriculum was obscuring students' understanding of the relationships among disciplines (Dewey, 1915; Harrison et al., 2020). If education were to reflect the interdisciplinary world that students inhabit, they would engage in content that seamlessly crosses subject matter disciplines thereby removing the disconnect between in-school disciplinary learning and out-of-school integrated life experiences (Figure 1).

Figure 1. Departmentalized Education Versus Interdisciplinary World



Over a century of calls for interdisciplinary education. The notion of *interdisciplinary education* dates to calls for "integrated" education in the late 1800s (Klein, 2006). In the 1920s, progressivists' view of social democratic education included the idea of integrated education and stressed placing personal and social concerns at the center of students' educational experiences. The term "integrated curriculum" appeared with the project approach to education in the 1920s, the core curriculum movement in the 1930s, and the problem-centered core curriculum movement in in the 1940s and 1950s. In the 1960s, the middle school movement called for a shift to "curriculum integration" through the implementation of interdisciplinary teaching teams. A student-centered curriculum distinguished the middle school model from the junior high model, which was based on a subject-centered curriculum (Harrison et al., 2020). Throughout the 1980s and 1990s, the term "curriculum integration" expanded such that it became a generic term for any "innovative" education approach that drew on more than one subject (e.g., thematic studies, multisubject designs, integrated units) (Beane, 1997; Klein, 2006). However, conventional disciplinary structures were beginning to take hold during this same period due in part to the advancement of school accountability and standardized testing. By the early 2000s, progress towards broader acceptance and implementation of interdisciplinary or integrated curriculum slowed substantially (Drake & Reid, 2020).

Despite the centrality of disciplinary structures, multiple current core content standards call for "integration" across disciplines. The Next Generation Science Standards emphasize integrated, interdisciplinary instruction which promotes intersections between science and other content areas, such as mathematics and English language arts (ELA), and encourages students to interact with authentic questions, problems, and phenomena (Harrison et al., 2020; National Research Council, 2013). Similar calls for interdisciplinary instruction exist within other core content standards, including the National Council for the Social Studies (2013), International Reading Association and National Council of Teachers of English (1996), and National Council of Teachers of Mathematics (2000) (Bintz & Monobe, 2020). Beyond content standards, the National Research Council highlights the need for K–12 education to address the increased demands for 21st-century skills, including problem-solving, collaboration, and the ability to work with multiple sources of knowledge and data. These 21st-century skills commonly require an interdisciplinary approach to instruction (Klein, 2006; National Research Council, 2012).

Next steps for interdisciplinary education. The limitations of a reliance on discipline-based instruction are becoming clear to many researchers and practitioners, underscoring the urgency to better understand

disciplinary integration and how interdisciplinary education can be implemented in schools and classrooms. Although projects claiming interdisciplinary approaches in education rose sharply in the past several decades, the field lacks a common understanding and definition (Klein, 2006). Many researchers have further called for descriptions of the forms that disciplinary integration can take (Czerniak & Johnson, 2014). Kaufman et al. (2003) raise key questions for consideration, including *What are actual disciplinary boundaries? When should disciplinary boundaries be crossed? How should they be crossed?*

The field of interdisciplinary education requires progress on multiple fronts, including clearer definitions of its current forms, an understanding of its context, whether and how students may benefit, and potential barriers and facilitating factors for implementation.

1.2 Research Questions and Methods

The following research questions guided the literature review:

How is interdisciplinary education currently defined and by whom? To what extent does interdisciplinary education overlap with or distinguish itself from other educational approaches, including multidisciplinary, transdisciplinary, and integrated education?

In what contexts (e.g., within traditional schools in core academic classes, electives, or career pathways; in nontraditionally structured schools; outside of formal school time), with what student populations, and in what contents or disciplines is interdisciplinary education practiced and researched?

What is the existing evidence base for interdisciplinary education on student outcomes? To what extent do outcomes vary across contexts, including by student demographics or school type?

What gaps currently exist in the research literature on interdisciplinary education?

1.3 Review Criteria

Relevant literature was identified by conducting keyword searches and database-specific subject term searches of the ERIC (via EBSCO), Web of Science, and PsycInfo electronic citation databases. The searches were conducted by RTI's professional librarians using the keyword combinations shown in Appendix A. The search was not limited to studies from the United States but only included articles published in the English language. The search was restricted to articles published between 2000 and 2021.

The initial search results yielded 116 items for Search 1 and 108 items for Search 2. The RTI team then screened abstracts for relevance to the research questions and prioritized articles from most to least relevant, reducing the number of reviewed items to 18 items for Search 1 and 30 items for Search 2. Two of the Search 1 items were books from which the team reviewed seven total chapters (articles). Three articles were pulled from Wineburg and Grossman (2000), including Applebee et al. (2000), Boix Mansilla et al. (2000), and Renyi (2000). Four articles were pulled from Harrison et al. (2020), including Bintz and Monobe (2020), Coffey and Fulton (2020), Moser et al. (2020), and Summers et al. (2020). Five

additional articles discovered through references supplemented the total. The final number of articles reviewed was 60.

2. Defining Interdisciplinary Education

The term "interdisciplinary education" does not have a single definition that is accepted by researchers and practitioners. As Applebee et al. (2007, p. 1,005) noted, "there is little consensus on terms and definitions to describe how different disciplines relate to one another and very little cross-referencing among authors who address issues in interdisciplinary studies." This lack of consensus makes defining and implementing interdisciplinary education challenging.

This section explores two approaches to defining interdisciplinary education. First, the focus is on an "intentional" definition of interdisciplinary education that describes what interdisciplinary education is (i.e., identifies its essential features) (Szostak, 2015). Multiple definitions are highlighted that are increasingly cited by interdisciplinary education researchers and areas of broad agreement and divergence across definitions are identified (Section 2.1). The next subsection shifts to an "extensional" definition of interdisciplinary education, identifying how interdisciplinary education is practiced, conducted, or implemented through interdisciplinary teaching and learning (Szostak, 2015) (Section 2.2). Finally, because multiple scholars have noted that interdisciplinary education exists on a continuum of disciplinary integration, the section concludes with a description of several continuums that further clarify the definition and implementation of interdisciplinary education (Section 2.3).

2.1 What Is Interdisciplinary Education?

Key Findings

While no single definition of interdisciplinary education exists, several definitions have common features:

- Disciplines as the foundation upon which insights and learning are made
- Involvement of two or more disciplines
- Explicit integration of disciplines to answer a complex question or solve a complex problem

Several frequently cited definitions of interdisciplinary education have grown out of the advancement of interdisciplinary studies in postsecondary education. Newell (2013, p. 24) defines interdisciplinary education as "a process of answering a question, solving a problem, or addressing a topic that is too broad or complex to be dealt with adequately by a single discipline or profession . . . [Interdisciplinary studies] draws on disciplinary perspectives and integrates their insights into a more comprehensive perspective." This definition has several key components, including specifying that (a) interdisciplinary education is a *process*, (b) the justification for an interdisciplinary approach is the breadth or complexity of whatever is being studied; and (c) the intended outcome is comprehensive understanding (Newell, 2013). It is critical to note that interdisciplinary teaching that does not integrate subjects or draw on the disciplines is *not* interdisciplinary.

By 2004, the National Academy of Sciences had developed a definition of interdisciplinary research that has since been transferred to the definition of interdisciplinary education: "Interdisciplinary research is a mode of research by teams or individuals that integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or area of research practice" (National Academy of Sciences, 2004). Moser et al. (2020) draw on aspects of this definition to define interdisciplinary education as involving two or more disciplines that work together "to advance fundamental understanding … beyond the scope of a single discipline or area" in research on interdisciplinary education. Drake and Burns (2004) engage a similar definition, writing, "an interdisciplinary approach gives equal attention to two or more disciplines and involves the explicit assimilation of concepts from the chosen areas."

Finally, Boix Mansilla (2005, p. 16) provides the following definition of interdisciplinary education: "The capacity to integrate knowledge and modes of thinking drawn from two or more disciplines to produce a cognitive advancement—for example, explaining a phenomenon, solving a problem, creating a product, or raising a new question—in ways that would have been unlikely through a single disciplinary means."

Toward a consensus definition. Although incorporating slightly different language, commonalities exist across each of these definitions that point to an emerging consensus definition. First, interdisciplinary education requires the disciplines as these are the foundation upon which insights and learning are made (Szostak, 2015). Second, it must draw on more than one discipline as part of its substantive focus (i.e., the focus must require more than a single perspective). Third, interdisciplinary education must involve an explicit integration of the disciplines so that the learner is solving a problem, addressing an issue, answering a question, explaining a phenomenon, or creating a new product.

2.2 How Is Interdisciplinary Education Implemented and Practiced?

Key Findings

- Common characteristics of interdisciplinary instruction include
  - encouraging explicit connections across disciplines,
  - engaging a thematic approach that can involve a single teacher or teams of teachers,
  - shifting the role of teacher from expert or specialist to facilitator or generalist, and
  - active student engagement through collaborative work and group discussion.
- Project-based learning, when drawing upon two or more disciplines, is the instructional approach most closely aligned with interdisciplinary education.

Extensional definitions, with an explicit focus on how interdisciplinary education is implemented and practiced, can reduce some of the ambiguity that exists in more formal definitions (Szostak, 2015). Although there is not a unique interdisciplinary pedagogy, there are emerging best practices (Klein, 2006). This section focuses on common approaches and practices within interdisciplinary teaching and learning.

Explicit connections. Interdisciplinary teaching requires teachers to organize the curriculum around common learnings across disciplines while focusing on an issue, problem, or question. Teachers "chunk together the common learnings embedded in the disciplines to emphasize interdisciplinary skills and

concepts" (Drake & Burns, 2004). Teachers make explicit connections between subject areas or explicitly ask students to integrate insights from different disciplines so that students can see the perspectives underlying each discipline and then develop a more holistic understanding of the issue, problem, or question (Klein, 2006; Newell, 2013; Szostak, 2015; Wang et al., 2020).

Thematic approach. Interdisciplinary curriculum engages a thematic approach with subjects or disciplines serving as tools for studying the theme, problem, or question of focus (Klein, 2006). Themes address cross-curricular issues in social, political, or economic realms which necessitate interdisciplinary teaching. Interdisciplinary teaching can take multiple forms, from a single teacher to large team teaching. Similarly, the implementation structure may vary (e.g., engaging two subjects in a single unit to an entire educational experience or focus as in an "academy" or "school-within-a school").

Teacher as facilitator. Teachers engaging in an interdisciplinary approach do not deliver content for their students to absorb but instead act as facilitators, mentors, coaches, or guides. Drake and Burns (2004) note that teachers shift from specialists in given subjects or disciplines to generalists who organize learning activities around essential questions, themes, or concepts and help students make connections. Teachers serve as model interdisciplinarians for students by guiding and coaching but not by serving as an expert (Newell, 2013). In fact, teachers themselves are often learners exploring new ideas during interdisciplinary instruction.

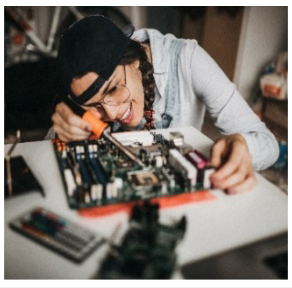
Active student engagement. Interdisciplinary education requires active student engagement in the exploration of challenging subject matter. Teachers can promote this by emphasizing tools students need to explore new ideas and examine multiple perspectives and by encouraging interaction within the classroom through open discussion rather than memorization and recitation (Applebee et al., 2007). Active student engagement may include collaborative learning; theme-based or problem-focused courses; projects and case studies; groups for discussion, games, and role playing; inquiry-based learning; learning portfolios; and experiential and service learning (Klein, 2006).

Instructional flexibility. Interdisciplinary approaches provide flexibility with respect to time and focus of instruction. For example, in an elementary setting, literacy may not require a separate time for instruction but can be integrated into other instructional time in service of learning other disciplines (Bintz & Monobe, 2020). For middle and high schools, instruction might occur in back-to-back block schedules that facilitate interdisciplinary collaboration across teams of teachers.

In the end, interdisciplinary teaching should result in interdisciplinary learning on the part of the student. Interdisciplinary learning requires unique skills of the learner, including reflective thinking, problem-solving, and searching for completeness and meaning (Klein, 2006). In this student-

Project-Based Learning Is Consistent With Interdisciplinary Education

The core tenets of project-based learning, including its student-centered, inquiry-based design and authentic real-world connections, are consistent with the definition of interdisciplinary education. Assuming that the project requires students to draw on insights from multiple disciplines, project-based learning is an instructional approach that most closely aligns with interdisciplinary instruction (Drake & Reid, 2020).



centered approach, students demonstrate interdisciplinary understanding when they can use what they have learned to solve a problem, create a product, or explain a phenomenon (Boix Mansilla et al., 2000).

2.3 Similarities and Differences With Related Approaches: Integration as a Continuum

Key Findings

- Multiple models place interdisciplinary education on an integration continuum, with intradisciplinary (single disciplinary study) on one end and transdisciplinary (complete integration of disciplines in service of answering student-driven problems or questions) on the other end.
- Although most models are presented as a hierarchy of integration, there is no one model that is best in all contexts.

Where does interdisciplinary education fit within the broader context of integrated education approaches? How similar or different is it from other frequently referenced approaches, including multidisciplinary, cross-disciplinary, transdisciplinary, and integrated education? Multiple scholars have placed curriculum integration approaches on a continuum, with differences related to the role of disciplines, practical applications, and underlying goals (Klein, 2006). Several continuum models are presented, with points of overlap and divergence highlighted.

2.3.1 Similarities Across Continuum Models

The following four categories are common, with similar definitions, across multiple continuum models: *disciplinary* (or *intradisciplinary), multidisciplinary*, *interdisciplinary*, and *transdisciplinary* (Applebee et al., 2007; Drake & Burns, 2004; Gresnigt et al., 2014; Kaufman et al., 2003; Klein, 2006; Weinberg & Sample McMeeking, 2017).

Disciplinary* or *intradisciplinary education is the study of a single discipline, or what is commonly understood as the traditional educational subjects without inclusion of content beyond the specific class subject (Weinberg & Sample McMeeking, 2017). Integrating subdisciplines within a subject area (e.g., reading writing, and oral communication within language arts) is still considered disciplinary or intradisciplinary (Drake & Burns, 2004).

Multidisciplinary is an intermediate step between intradisciplinary and interdisciplinary. Multidisciplinary education "juxtaposes" disciplines, with each discipline contributing knowledge in an additive way and each discipline remaining intact (Klein, 2006). Students are typically left to identify the connections among disciplines themselves. In multidisciplinary approaches, team teaching typically does not occur. Instead, classes may focus on a similar theme but be taught separately (Weinberg & Sample McMeeking, 2017). Multidisciplinary is synonymous with "correlated knowledge," "complementary," "parallel," "webbed," or "sequenced" approaches (Applebee et al., 2007).

Interdisciplinary moves beyond the multidisciplinary approach by attempting to integrate two or more disciplines through an explicit focus on a blending of the disciplines and integrating the contributions of several disciplines to explore and understand the thematic unit (Kaufman et al., 2003). Teachers organize the curriculum around common learnings across disciplines (Drake & Burns, 2004).

Instructional units can be taught by one or more teachers, but the instruction always draws from multiple disciplines, requires synthesis of knowledge from different disciplines, and is based on a thematic unit that is designed to solve a problem or issue (Weinberg & Sample McMeeking, 2017).

Transdisciplinary is similar to interdisciplinary but with several additional practices that push it "beyond" the disciplines. Whereas interdisciplinary begins with the disciplines, transdisciplinary approaches begin with the issue or problem and, through the process of problem-solving, engage the disciplines as needed to reach a solution (Meeth, 1978). Learning is student centered with teachers organizing learning around student questions rather than around teacher-determined questions or themes (Drake & Burns, 2004). *Integrated* or *integrative* is often synonymous with *transdisciplinary* (Harrison et al., 2020).

Focus on Integrated Science, Technology, Engineering, and Mathematics (STEM)

Integrated STEM is an example of interdisciplinary or transdisciplinary education. Engineering and technological design is at the center of integrated STEM instruction with students engaging in real-world problem- and design-based tasks. Teachers help students make connections across science and mathematics concepts and can further enrich instruction with connections across arts, literature, and social studies (Havice et al., 2018; National Research Council, 2014).

Because teaching is typically disciplinary, the gulf between traditional instructional approaches and transdisciplinary approaches is the widest on the continuum and therefore the most difficult to reach (and teach) within traditional organizational structures of schools (Kaufman et al., 2003). Transdisciplinary approaches exhibit the most integrative restructuring. In this approach, disciplinary subjects and boundaries are blurred such that a new organizational framework in schools is often required (Klein, 2006). Synonymous terms include "integrated curriculum," "unified studies," and "fusion studies."

2.3.2 Differences Across Continuum Models

Several continuum models have a different or additional level of integration.

- ***Predisciplinary*** is defined as a study organized around a common theme that does not draw extensively on disciplinary ways of knowing (Boix Mansilla et al., 2000). These types of thematic predisciplinary curricula are common among younger students, especially in pre-elementary and elementary levels, and included in continuum described by Applebee et al. (2007) and Wu et al. (2021).
- ***Cross-disciplinary*** is an approach that "crosses" more than one discipline and may occur, for example, when "a teacher offers real-world examples that draw from other disciplines to offer context for a particular content topic" or when viewing one discipline from the perspective of another (Meeth, 1978). Weinberg and Sample McMeeking (2017) include this approach in their model that also includes intradisciplinary, multidisciplinary, and interdisciplinary approaches.
- ***Connected or aware*** and ***nested or fused*** are approaches that exist between disciplinary and multidisciplinary approaches. *Connected or aware* is defined as separate disciplines taught by separate teachers but with explicit connections made between the separate disciplines, and

nested or fused is defined as content from one discipline being used to enrich the teaching of another discipline. Gresnigt et al. (2014) included these additional steps in a model curriculum integration.

Table 1 summarizes these multiple continuums, presenting an overview of the overlap and differences among types of curricular integration.

Table 1. Synthesis of Integrated Curriculum Continuums

Integrated curriculum continuums					Description
Weinberg et al. (2017)	Applebee et al. (2007); Wu et al. (2021)	Drake & Burns (2004); Drake et al. (2020); Kaufman et al. (2003)	Harrison et al. (2020)	Gresnigt et al. (2014)	
	Predisciplinary				Common in early education and involves exploration of a wide range of features of a common activity or theme but is not discipline based
Intradisciplinary	Disciplinary	Disciplinary		Fragmented, cellular, or isolated	Usually represented by traditional school subject areas
Cross-disciplinary				Connected or aware Nested or fused	Views one discipline from the perspective of another discipline
Multidisciplinary	Correlated	Multidisciplinary*		Multidisciplinary	Studies a topic from the perspective of several disciplines at one time but makes no attempt to integrate their insights
Interdisciplinary	Shared *(synonymous with Integrated)*	Interdisciplinary*	Interdisciplinary	Interdisciplinary	Integrates two or more disciplines through an explicit focus on blending the disciplines and integrating the contributions of several disciplines to explore and understand a thematic unit
	Reconstructed *(synonymous with Integrated)*	Transdisciplinary*	Integrated or integrative	Transdisciplinary	Begins with the issue or problem and, through the process of problem-solving, engages the disciplines as needed to reach a solution to a complex issue

2.4 Implications of Interdisciplinary Education Definitions

Having an agreed-upon definition of interdisciplinary education and related educational approaches has implications for how it can be further conceived, approached, and implemented in elementary and secondary education in the United States. Moving from a disciplinary to interdisciplinary approach would have ramifications on multiple aspects of the educational sector, including the organizational structures, institutional cultures, teacher preparation programs, curriculum selection, academic standards, budgets, and professional development (Klein, 2006).

It is critical to note that while the definition of interdisciplinary education and the various continuum models provide a useful way to consider the educational content, approach, and activities of teachers and students, any particular teacher, team of teachers, or classroom may move "up" or "down" the continuum at various points throughout a school year (Applebee et al., 2007). Some periods may see instruction entirely discipline based because students require foundational disciplinary knowledge, while other periods may focus on integration and connections across subjects. Although the continuum may appear to present a hierarchy with more integrated curriculum as "better," this interpretation is not necessarily appropriate. Given the current era of standards and accountability, no one approach dominates in all contexts (Drake & Reid, 2020).

3. Contexts of Interdisciplinary Education Implementation

This section documents the settings of interdisciplinary education (in school vs. out of school and school type), disciplines or content areas engaged, and student populations involved based on the literature reviewed. A comprehensive account of where, how, and with whom interdisciplinary education is occurring is not known to exist. This summary provides the range of contexts from studies that reported implementing interdisciplinary, transdisciplinary, or integrated science, technology, engineering, and mathematics (STEM) approaches but does not describe the extent to which this is representative of all interdisciplinary education implementation across K–12 education in the United States.

3.1 Settings and Student Populations

Key Findings

- Most interdisciplinary education occurs in in-school settings with evidence of implementation at all levels (elementary, middle, and high school).
- Diverse student populations have been reported engaging in interdisciplinary education, with multiple studies conducted in schools serving majority low-income student populations.

The vast majority of interdisciplinary education studies have occurred in in-school settings, with many examples from traditional public schools at the elementary school level (Liao, 2016; Park Rogers, 2011; Rodriguez-Valls, 2012; Romance & Vitale, 2012; Thomas, 2012; Yang et al., 2018; Yoon et al., 2014), middle school level (Applebee et al., 2007; Boix Mansilla et al., 2000; Cross et al., 2017; Gale et al., 2020;

Gardner & Tillotson, 2019; Harrison et al., 2020; Stohlmann et al., 2012; Thomas et al., 2012; Wu et al., 2021) and high school level (Applebee et al., 2007; Pierce & Hernandez, 2014; Weinberg & Sample McMeeking, 2017). Several instances of interdisciplinary education at selective enrollment public schools were documented (Applebee et al., 2007; Harrison et al., 2020; Koh, 2012). Far fewer accounts of out-of-school interdisciplinary programs have been documented. In one instance, Ching et al. (2019) studied a STEM-focused after-school program that took place in a community center serving a Title I elementary school and involved teachers from the elementary school.

The student populations served by interdisciplinary education programs varied widely in terms of racial and ethnic background, socioeconomic status, and urbanicity. Multiple programs were implemented in schools serving majority low-income student populations. Applebee et al., (2007) described an interdisciplinary curriculum implemented in a large California high school where 91% of students were eligible for free lunch, 77% of students were Hispanic, and 22% were African American. Romance and Vitale (2012) implemented their interdisciplinary program in a large, racially diverse urban Florida district with 40% of students eligible for free lunch. Other studies reported implementation of interdisciplinary education at affluent schools. In his study of middle and high school programs, Applebee et al. (2007) highlighted an interdisciplinary program in a New York public high school that was 92% White with only 5% of students eligible for free lunch.

Although many of the earliest progressive schools that followed Dewey's call for progressive education and implemented interdisciplinary education were private schools serving affluent students, most likely due to the associated costs (Semel, 1999), the recent research on interdisciplinary education since 2000 has focused on the implementation of these educational approaches in public schools serving more diverse students.

3.2 Content and Disciplines

Key Findings

- Interdisciplinary education has been implemented across a wide range of contents and disciplines, including humanities only (e.g., art, philosophy, social studies, English), humanities plus STEM disciplines, STEM only (e.g., integrated STEM), and STEM plus career and technical education.

The content covered in interdisciplinary education varies considerably across education levels and the themes selected to drive inquiry. Klein (2006) notes, "for younger children, teachers often select themes related to animals and marine ecology, the planetary system, and space exploration. At varying levels of complexity across school and college, students explore themes in history (e.g., immigration, genealogy, exploration, and war), social problems (e.g., conflict, hunger, poverty, racism, AIDS, drug use, ethnic tensions, and pollution), institutions (e.g., family, community, and government), systems (e.g., transportation, the economy, and ecology and the environment), and abstract concepts (e.g., conflict, change, democracy, responsibility, and globalism)."

Example discipline and content of interdisciplinary programs include (a) humanities units that integrate English, social studies, art, or philosophy (Applebee et al., 2007; Bintz & Monobe, 2020); (b) units

integrating STEM and humanities (Cross et al., 2017; Gresnigt et al., 2014; ; Liao, 2016; Rodriguez-Valls, 2012; Wu et al., 2021); (c) integrated STEM units (Gale et al., 2020; Weinberg & Sample McMeeking, 2017); and (d) units integrating career and technical education (CTE) with academic disciplines (Pierce & Hernandez, 2014; Canuteson, 2017; Clayton et al., 2010; Roberts et al., 2018; Tews, 2011). Text below highlights several examples from each category.

Humanities
An interdisciplinary curriculum for 9th-graders at a California high school focused on non-Western studies, blending perspectives from English, social institutions (a version of social studies), and art and art history (three separate full-time "core" classes). The curriculum was organized around a year-long conversation about non-Western cultures. A 5-week introductory unit on tolerance encouraged students to be sensitive to others' cultures and beliefs and to be accepting of cultural differences. Concepts such as cultural relativity, ethnocentrism, and dehumanization were studied and discussed through literature, religion, social history, and art history (Applebee et al., 2007).
The Responsible Change Project, a middle school interdisciplinary unit, was based on the College, Career, and Community Writers Program curriculum (part of the national Writing Project) combined with critical literacy and service learning to promote a social justice perspective. Teachers attended a 10-day summer institute to learn how to guide students through source-based argument writing, mini-units, extended research arguments, and formative assessments (Coffey & Fulton, 2020).
Science, technology, engineering, and mathematics (STEM) and humanities
An arts integration with STEM content in an elementary setting had students create a physical 3D storybook that could be used to teach a concept by acquiring and utilizing science, technology, engineering, art, and mathematics knowledge and skills. The project integrated language arts (children's literature), science, technology, engineering, art, and math. Over a 3-week period, the students worked in groups to create interactive 3D storybooks to teach the concept of embracing difference (Liao, 2016).
An integrated scientific argumentation unit for middle schoolers centered on the topic of astrobiology. Lessons were oriented in a project-based format with students situated as explorers on a NASA mission. Students completed activities in science and English courses as well as in the library with student tackling the following driving question: Where might we find life outside of Earth in our solar system? Unit activities guided students to develop a well-researched and defensible stance on their response to the driving question. Students engaged in hands-on inquiry activities in science and rich discussion (Summers et al., 2020).
Integrated STEM
The Bio-Math Connection (BMC) is an interdisciplinary project-based learning program with 15 instructional modules. Each BMC module was codesigned by a different interdisciplinary team of experts, including a mathematician, a biologist, a curriculum development expert, and a high school teacher. Each module consists of four to six units, with units taught over 1–2 weeks. Unit activities include materials for both teachers and students (Weinberg & Sample McMeeking, 2017).
Through the TRAILS program (Teachers and Researchers Advancing Integrated Lessons in STEM), funded by the National Science Foundation, a high school integrated STEM effort involved collaborations of teacher pairs consisting of an engineering technology education and a life sciences teacher. They worked together to implement integrated STEM lessons using engineering design and science inquiry practices, biomimicry, and 3D printing to enhance learning STEM concepts (Kelley et al., 2021).
Career and technical education and STEM
Geometry in Construction is a high school STEM-based program that blends mathematical content with construction design principles and is taught by a two-teacher team. The program incorporates curriculum, instruction, and assessment strategies, with students applying learning in a real-world, project-based environment. The course was developed by aligning the common core state standards for geometry with the sequence of constructing a house which allowed for "seamless cross-discipline integration" (Canuteson, 2017).

In addition to teacher-developed units, several more established interdisciplinary curricula that integrate science and literacy or reading exist, as summarized in Gresnigt et al. (2014).

- In-Depth Expanded Applications of Science (**IDEAS**) is integrated science and literacy instruction for students in grades K–5 that consists of six key conceptually linked instructional elements that occur in blocked schedule format (empirical inquiry or hands-on activities, content-area reading comprehension, propositional concept-mapping, journaling and writing, projects, prior knowledge or cumulative review) that are linked to the core concept curricular framework and are flexibly arranged by teachers to allow for student conceptual understanding.
- **Seeds of Science / Roots of Reading** is a curriculum that integrates science and literacy to provide students access to in-depth science knowledge, academic vocabulary, and skills and strategies in both literacy and science. The curriculum includes 12 units that have been developed and tested.
- Achieving Integrated Math and Science (**AIMS**) builds science and math knowledge and skills through a student-centered inquiry and discourse-based approach. Its integrated activities and model of learning are based on students counting and measuring during hands-on real-world experiences, recording measurements, and writing about them. Students illustrate findings with graphic representations to improve abstract thinking, including hypothesizing, generalizing, and analyzing.

3.3 Equity Considerations in Interdisciplinary Education

Key Findings

- Accountability and achievement pressures can restrict opportunities to implement interdisciplinary education.
- Because low-performing schools face the greatest pressure to improve math and ELA achievement among their students, and because low-performing schools disproportionately serve low-income students and students of color, interdisciplinary education faces equity challenges.

Within the current context of educational accountability, tensions exist for educators and administrators working in low-performing schools. On the one hand, schools with low performance on state standardized tests are often under extreme pressure to raise their proficiency levels, particularly on math and ELA tests. As a result, schools often narrow the curriculum to focus on these two focal disciplines at the expense of other disciplines and interdisciplinary approaches (Romance & Vitale, 2012). On the other hand, devoting instructional time to improve students' performance on math and ELA disciplinary assessments to the exclusion of other disciplinary content or interdisciplinary curriculum has negative consequences on long-term learning outcomes. As Romance and Vitale (2012) note, it is then not surprising that students who received predominantly math and ELA disciplinary instruction perform poorly in content-based science courses and other disciplines requiring deeper levels of reading comprehension during their middle and high school years. The narrowing of disciplines in the early grades stunts students' later growth by "withholding the exact form of intellectual capital they need for

subsequent academic success." As lower performing schools disproportionately serve low-income and Black and Hispanic students, interdisciplinary education and access to it is an issue of educational equity.

Multiple researchers have noted that lack of administrator support is a substantial barrier to the adoption of interdisciplinary education (Hayward, 2017; Weinberg & Sample McMeeking, 2017). Teachers need supportive environments from their administrations to learn, experiment, and adopt new instructional approaches. When school leaders themselves feel accountability pressure to have their students "perform" on standardized tests, it makes it unlikely that they can create a sufficiently supportive environment to facilitate teachers' implementation of interdisciplinary curricula. Hayward (2017) notes that administrator support for teachers "is very important in such an endeavor for they can enhance or deny resources or opportunities dedicated to integrated STEM" and other interdisciplinary education approaches.

Even in schools where administration is supportive of teachers implementing interdisciplinary education approaches, an interdisciplinary education approach requires significant teacher commitment and self-efficacy. Teachers with more years of experience and higher levels of teaching self-efficacy are more likely to be capable of and motivated to design appropriate lessons incorporating multiple disciplines, draw appropriate connections among disciplines, and explain or understand appropriately related content disciplines (Hayward, 2017). Given that more experienced teachers tend to teach in better resourced districts and serve fewer low-income students and students of color (Goldhaber et al., 2015), opportunities for interdisciplinary education are likely unevenly distributed across the student population.

Finally, as described by Renyi (2000), initiatives to implement interdisciplinary programs in districts serving large proportions of low-income students are often grant funded. Although sustainability of programs is typically included in the original vision of the program, efforts to implement interdisciplinary education can fade once grant funding ends. Without plans for how to continue and sustain programming after the grant period and in the face of retirement or teacher turnover, whole-school efforts that provide all students the opportunity for interdisciplinary education are reduced.

3.4 Facilitating and Inhibiting Factors in Interdisciplinary Education Implementation

Key Findings

Factors inhibiting interdisciplinary educational approaches in schools include

- standards and accountability policies that narrow the curriculum and put pressure to raise achievement in discrete disciplines and
- rigid school structures that prevent sufficient planning time or teacher collaboration opportunities.

Factors that facilitate the effective implementation of interdisciplinary education include

- principal support that gives teachers time and resources to develop and deliver interdisciplinary units,
- teacher motivation and commitment to interdisciplinary instruction, and
- a collaborative teaching environment.

Multiple factors can either limit or promote the effective implementation of interdisciplinary education. Factors that fall within three larger categories are highlighted: federal, state, and district policy; school organizational structures and supports; and teacher knowledge and motivation.

3.4.1 Federal, State, and District Policy

One major deterrent to implementing interdisciplinary approaches at the elementary and secondary level is that state standards and achievement tests are organized around traditional subject areas, with a primary focus on reading and mathematics assessment and a secondary focus on science, social studies, and civics (Vars et al., 2000; Rodriguez-Valls, 2012). Although there is pressure for teachers and school leaders to make adequate gains in these disciplinary tests each year, there is not any policy pressure encouraging the integration across subject areas. Another policy barrier to a broader acceptance and implementation of interdisciplinary education is the sheer volume of competencies specified in standards that teachers are required to cover and the lack of sufficient instructional time to cover them (Vars et al., 2000). Teachers are pressed to cover the disciplinary material, leaving little time for interdisciplinary exploration.

3.4.2 School Organizational Structures and Supports

Schools' organizational structures can influence whether interdisciplinary approaches can be implemented and sustained. Shifting from a disciplinary to interdisciplinary approach requires significant planning time from teachers. School schedules that allow teachers sufficient individual and coplanning time facilitate successful interdisciplinary implementation (Park Rogers, 2011). Coplanning sessions provide teachers with opportunities to give each other support, have consistent check-ins, and ensure they are following their curriculum, meeting learning objectives, and meeting the learning needs of their students. In addition, school structures that allow teams of teachers to have back-to-back block schedules facilitate interdisciplinary instruction, particularly in middle and high school, by providing teachers flexibility to collaborate and team teach as needed (Weinberg & Sample McMeeking, 2017). At the elementary level, the ability to have the school schedule devote time to instruction in subjects outside of ELA and math is critical (Gresnigt et al., 2014; Romance & Vitale, 2012).

Teachers require significant support to gain the knowledge and skills required to create and implement an integrated curriculum. These cannot be gained through a single professional development workshop or in-service day (Caskey, 2002). Instead, structures to provide continual support to teachers are needed, including significant allocation of time. In addition to planning time, teachers need support in the form of professional development time and opportunities, preparation and setup time, and time to learn along the way (Wu et al., 2021). Multiyear investment in teachers is sometimes necessary so that they can overcome initial barriers and successfully implement enough lessons to "own" the interdisciplinary approach (Gresnigt et al., 2014). The resources required are not insignificant.

3.4.3 Teacher Knowledge and Commitment

Teacher knowledge and motivation play a role in effective interdisciplinary education implementation (Gardner & Tillotson, 2019; Pearson, 2017). Integrating curriculum is challenging; many teachers have little training in designing interdisciplinary units and may not feel prepared to extend beyond their disciplinary expertise (Caskey, 2002; Weinberg & Sample McMeeking, 2017; Wang et al., 2020; Wu et al., 2021). The teacher certification system prioritizes single-subject-area expertise and places little focus on integration of subjects during preservice preparation (Gardner & Tillotson, 2019). Once in the classroom, teachers have little access to established interdisciplinary curricular resources (Weinberg & Sample McMeeking, 2017). When teachers can access established curriculum (e.g., Seeds/Roots), they find it effective (Gresnigt et al., 2014).

In addition to teacher knowledge, teacher motivation and confidence are important considerations in whether a school or teaching team is ready for interdisciplinary instruction (Applebee et al., 2007). Without a deep commitment to the work, implementation is not likely to succeed. Finally, in cases where teams of teachers are implementing interdisciplinary units, teachers must have a working relationship characterized by trust and willingness to collaborate (Harrison et al., 2020; Applebee et al., 2007; Renyi, 2000).

Drake and Reid (2020) summarize the challenges around interdisciplinary education, noting, “so far, widespread implementation of [integrated curriculum] has been hampered by practical and theoretical challenges. These include ambiguity around definitions, issues with measuring interdisciplinary knowledge and behaviors, logistics such as scheduling and reporting protocols, territorial battles, teacher identity as a subject expert, and resistant educators.” A widespread implementation of interdisciplinary educational approaches will require coordinated, systematic change across multiple levels.

4. Student Outcomes

The rationale behind the benefits of interdisciplinary education for student learning is well accepted; however, published studies examining the impact on student outcomes is still not extensive. Early literature reviews concluded that students in interdisciplinary programs "do as well as, and often better than, students in conventional departmentalized programs" (Vars et al., 2000). Other reviews reported the benefits of interdisciplinary education on student motivation, interpersonal skills (Drake & Reid, 2020), higher level thinking skills, and mastery of content, (Ellis & Fouts, 2001). Although the number of studies reviewed is considerable, the research evidence is still inconclusive on the benefits of interdisciplinary education (Ellis & Fouts, 2001).

This section examines studies of interdisciplinary programs in K–12 schools within the United States published after 2000. Studies that reported implementing interdisciplinary curriculum were included and were not further screened for specific instructional practices. Multiple study designs, including qualitative and quantitative as well as experimental and nonexperimental, are included.

4.1 Cognitive Outcomes

Key Findings

- Several reviews suggest positive effects of integrated education, particularly for math and science achievement, but additional research is needed.
- Across multiple studies, students engaged in interdisciplinary education units demonstrate increased knowledge on student knowledge tests.
- Overall, the literature on the impact of interdisciplinary education is still relatively thin.

4.1.1 Academic Achievement

Several reviews since 2000 have summarized the effects of interdisciplinary education or integrated STEM education on students' cognitive outcomes. Becker and Park (2011) conducted a meta-analysis of results of studies of integrated STEM approaches on student learning (28 studies, 33 effect sizes). The largest effects of integrated STEM education were evident at the elementary level relative to older grades, and larger effects were found when the instructional approach integrated all four subject areas (science, technology, engineering, and math) rather than two or three areas. They conclude that their results are preliminary and emphasize the need for further research.

In a 2014 review article, Gresnigt et al. summarized the cognitive outcomes for elementary students from three U.S.-based interdisciplinary programs: IDEAS, Seeds/Roots, and AIMS. They report increased science and reading achievement in IDEAS classrooms relative to comparison classrooms. IDEAs also exhibits "transfer" effects, with improved science and reading comprehension levels in 6th–8th grades based on program exposure during the elementary years (Romance & Vitale, 2012). Seeds/Roots reported improved understanding of the content and nature of science among its participants relative to control groups but no significant learning effects for reading or writing. They conclude that, overall, the reported effects of interdisciplinary programs are generally positive and in line with previous research summaries (Vars et al., 2000).

Several recent single studies at the high school and elementary level find promising effects of interdisciplinary approaches on math and science achievement. At the high school level, Canuteson (2017) found that students who took an integrated course combining mathematics and CTE in a project-based environment had higher math achievement at the completion of the course than students who received traditional mathematics instruction. A second study of an integrated course of math and CTE found more mixed results, with no statistically significant differences in math achievement between the comparison group and treatment group but positive statistically significant differences in reading achievement (Pierce & Hernandez, 2014). At the elementary level, Harris (2020) found that 4th-grade students attending schools with an interdisciplinary curriculum had higher scores on math and science Grade 4 PARCC tests than a matched comparison sample of students attending schools with a traditional subject-specific curriculum. Results from this study are suggestive of a positive effect but, given the nonexperimental study design, should not be considered conclusive.

4.1.2 Knowledge and Skills

Available evidence of the impact of interdisciplinary education on knowledge and skills similarly suggests positive results. For instance, in one study, Yoon et al. (2014) found that among 2nd– to 4th–grade students, those receiving an integrated science, technology, and engineering curriculum scored significantly higher student knowledge test scores across all three grades. Students in the treatment group also had significantly higher scores than the control group on the engineering career subscale, indicating higher interest and aspirations in the engineering field. A second study (without a control group) of 2nd– and 3rd–grade students found that participation in an integrated science course (*Engineering is Elementary*) found a positive and significant effect of engineering instruction over the course of 2 academic years. Students demonstrated improvements in their understanding of basic engineering concepts on student knowledge tests.

4.2 Noncognitive Outcomes

Key Findings

- Evidence on the impact of interdisciplinary education on student attitudes and engagement is mixed.
- Although the research literature has begun to provide initial evidence for the ability of interdisciplinary education approaches to produce positive noncognitive outcomes, including improved attitudes, engagement, collaboration, and communication, the current evidence base is insufficient to conclusively determine the benefits.

Many of the purported benefits of interdisciplinary education include noncognitive outcomes such as improved engagement, attitudes towards learning, communication, and collaboration. Several studies report results from quantitative survey scales; others rely primarily on qualitative methods, including open-ended survey responses, focus groups, or teacher interviews. These studies tend to provide rich insights into student and teacher perceptions but do not provide generalizable evidence of impact.

4.2.1 Attitude and Engagement

Results related to student attitudes and engagement are somewhat mixed. Several studies, using pre- and post-surveys, report decreases or no change in student attitudes following participation in the interdisciplinary program (Cross et al., 2017; Ching et al., 2019). After participation in a middle school robotics program, Cross et al. (2017) found significant decreases in student attitude scores related to curiosity, learning potential, and robotics and technology identity and no significant change for confidence. Ching et al. (2019) found that science attitudes among elementary students did not improve following participation in an integrated space-themed STEM program, but math attitudes did increase. Yoon et al. (2014) examined effects on student identity and found no significant differences between the treatment and control groups for the Engineering Identity Development Scale (EIDS) academic subscale, suggesting that the program did not affect students' beliefs about how they perform academically. However, across all three grades (2nd–4th), the treatment group scored significantly higher than the control group on the post-EIDS career subscale, suggesting improved understanding of engineering careers. Vogler (2003), in a case study of an integrated curriculum in middle school,

reported that students exhibited higher motivation and pride in their work during the unit and attributed their higher standardized test scores to increased confidence in the content material.

4.2.2 Collaboration and Communication

Results related to collaboration and communication skills also show mixed results. In one study of an integrated science and English argumentation unit, students were required to work in groups to conduct research and writing. Results indicated that students reported gaining positive collaboration and communication skills (Summers et al., 2020). Similarly, in a study of an arts integration unit, many students indicated growth in their collaborative skills and ability to work with group members to identify multiple ideas and problem-solve as a team (Liao, 2016). However, another study of an integrated robotics curriculum found that students had mixed reactions to teamwork (Cross et al., 2017). Some students frequently mentioned teamwork in responses to questions about their enjoyment of the project, while others described negative team experiences.

Klein (2006) notes that teacher observations of the use of interdisciplinary education approaches in their classrooms report multiple benefits for students. These include greater motivation to learn, increased capability of synthesizing learning, enhanced critical thinking, and greater creativity and thoughtfulness. As students advance from elementary to secondary and postsecondary, they are better able to locate and assess pertinent knowledge, discern patterns and connections, and create holistic understanding of themes or problems. These are all positive outcomes for students and aligned with much cited 21st-century skills that all students will need. Although the research literature has begun to provide initial evidence for the ability of interdisciplinary education approaches to produce these outcomes, the current evidence base is insufficient to claim these benefits with certainty.

5. Research Gaps in Interdisciplinary Education

Additional research is needed on

1. the impact of interdisciplinary education on student cognitive and noncognitive outcomes and the cumulative or long-term effects of exposure to interdisciplinary education;
2. the role of assessments in interdisciplinary education, both to better assess how interdisciplinary education affects knowledge and skills and to understand how interdisciplinary assessments can be developed and implemented within traditional school structures;
3. implementation practices, to identify the critical elements of interdisciplinary instruction and to identify the contextual and organizational barriers that must be overcome for successful implementation;
4. effective teacher preparation (preservice) and professional development (in-service) programs; and
5. how educators can use interdisciplinary education approaches to advance equity.

The wider acceptance and expansion of interdisciplinary education is currently limited by the lack of a clear, universally accepted definition and a relatively thin systematic research base (Wineburg & Grossman, 2000; Weinberg & Sample McMeeking, 2017). A significant amount of literature amounts to advocacy for interdisciplinary education based on over a century of thinking through the benefits of an interdisciplinary education that resembles the complex world in which students live (Applebee et al., 2007). Several main research gaps in the interdisciplinary education literature are identified below.

5.1 Student Outcomes

Although Ellis and Fouts (2001) noted this over two decades ago, it largely holds true today: "Experimental research on interdisciplinary curriculum is very difficult to conduct and, therefore, rather rare. The interdisciplinary curriculum is, itself, a large holding company of educational variables that, put together, defy classic research methods that attempt to isolate a single variable to show some degree of cause and effect." In their 2011 meta-analysis, Becker and Park noted the results should be "regarded as preliminary because there are very few empirical studies on the effects of integrative approaches among STEM subjects on students' learning." Since then, additional researchers have noted the scarcity of research relating interdisciplinary approaches to student learning, including on skills development (Harrison et al., 2020; Gresnigt et al., 2014). More research, both experimental and nonexperimental, is needed to understand whether academic benefits for interdisciplinary education exist, the level of integration required to elicit benefits, and the mechanisms that allow interdisciplinary instruction to improve learner outcomes.

Several scholars have additionally called out specific research gaps. Very little is understood about how exposure to interdisciplinary curriculum across multiple grades may have implications for student learning potential in relation to cumulative or development effects (Tafur et al., 2014). In addition, the long-term consequences of exposure to interdisciplinary education are not well known aside from a few isolated studies (Romance & Vitale, 2012).

A related gap in the literature focuses on student outcomes beyond those able to be measured with standardized tests. Yang et al. (2018) developed assessments to measure student understanding of cross-cutting concepts—an aspect of interdisciplinarity—as identified in the Next Generation Science Standards. More research is needed to measure how interdisciplinary education affects students' understanding of cross-cutting concepts and other skills such as critical thinking, collaboration, communication, confidence or self-efficacy, and motivation. Several authors have written on this topic, including Boix Mansilla (2005), Gao et al., (2020), and Kaufman et al. (2003), but additional research is warranted.

5.2 Implementation

Although several studies have examined the implementation practices of interdisciplinary instruction in the classroom (e.g., Applebee et al., 2007; Harrison et al., 2020; Wu et al., 2021, Weinberg & Sample McMeeking, 2017), additional research is needed to better understand interdisciplinary education approaches and the day-to-day implementation strategies across various contexts of K–12 education. Current research is insufficient on which elements of interdisciplinary instruction are critical to the practice (Thibaut et al., 2018). More attention is needed on the specific approach to interdisciplinary instruction, details on what instruction is included, and how it was supported by teachers, parents, and the administration (Pearson, 2017). Wang et al. (2020) also recommends that additional research is needed on the contextual and organizational barriers from school administrators' perspectives that could be mitigated to more effectively implement interdisciplinary instructional approaches in typically structured high schools.

5.3 Teacher Preparation and Professional Development

Multiple scholars have called for additional research on how teacher preparation and professional development affects the implementation and impacts of interdisciplinary education. Although the literature on student outcomes is thin, whether impacts from interdisciplinary instruction are seen on student outcomes may have less to do with the instructional approach and more to do with whether teachers can implement it confidently and competently. As noted by Havice et al. (2018), an interdisciplinary (or integrated) approach cannot occur "overnight," particularly not without thoughtful training for current and future teachers. What professional development exists, how widely it is available, and how effective it is are all critical aspects that should be further explored. Some preliminary evidence of one teacher professional development program (Integrative STEM Education Institute) suggests that participation leads to higher self-efficacy for integrated STEM education (Havice et al., 2018). Given the complexities of planning interdisciplinary lessons, many more opportunities for teacher preparation and professional development and a more thorough examination of their effects is needed (Harrison et al., 2020).

5.4 Equity in Interdisciplinary Education

Finally, additional research is needed to demonstrate whether interdisciplinary education can help achieve equitable outcomes for student learning. Current interdisciplinary education practices tend to take a "color-blind" approach to instruction but not one that disrupts current inequities in practice (Hurd et al., 2018, as cited in Harrison et al., 2020). More research is needed to demonstrate how educators can use interdisciplinary education approaches to help students think critically about their worlds and improve learner outcomes. In addition, given the limited number of rigorous studies on the impact of interdisciplinary instruction on student outcomes, little is known on the potential heterogeneous effects of interdisciplinary instruction by student subgroups. More research is needed on whether interdisciplinary education is effective, under what conditions, and for whom, in order to better understand implications for educational equity.

Part II: Landscape Analysis

1. Introduction

This landscape analysis is the second of two parts in the Interdisciplinary Education Literature Review and Landscape Analysis conducted by RTI International for Lucas Education Research. Based on interviews and focus groups with researchers, program developers, leaders of professional learning organizations, and practitioners, the report provides background information on interdisciplinary education, including definitions, examples, and evidence from research and practice. Additionally, it summarizes existing implementation barriers and highlights supports, resources, and policies needed to expand interdisciplinary learning opportunities for students.

The following research questions guided this landscape analysis:

- How is interdisciplinary education currently defined and by whom? To what extent does interdisciplinary education overlap with or distinguish itself from other educational approaches, including multidisciplinary, transdisciplinary, and integrated education?
- In what contexts, with what student populations, and in what contents or disciplines is interdisciplinary education practiced? What are existing examples of the approach?
- What is the current reach of interdisciplinary education? To what extent are there barriers to interdisciplinary approaches by student subgroups? What are the major roadblocks to adoption?
- To widen the reach of interdisciplinary education, what are the existing and needed supports and resources for practitioners? Existing and needed policies and structures?

Methods. The landscape analysis relies on interview data from 19 individuals who were identified through an environmental scan and literature review as leaders in the field of interdisciplinary education. Respondents held a variety of roles as researchers, curriculum and program developers, and leaders of professional learning or practitioner organizations (hereafter researchers). In addition, nine practitioners were interviewed, including three teachers, three school leaders, and three district leaders. The practitioners represented multiple grade levels (elementary, middle, and high school), school types (traditional vs. charter), subjects taught (science, technology, engineering, and mathematics [STEM] vs. non-STEM), and states, including Hawaii, Maryland, Michigan, New Mexico, North Carolina, and Virginia. Interviews were semistructured and lasted approximately 1 hour. All interviews, conducted between October and November 2021, were recorded and transcribed, then coded using thematic analysis to identify themes. (The full list of respondents appears in Appendix B. Appendix C presents practitioner and researcher protocols.)

Organization of the report. The following sections address goals of the landscape analysis: Section 2 summarizes definitions of interdisciplinary education and preferences for its use; Section 3 describes current practices in interdisciplinary education, including examples from classrooms. Section 4 covers the current reach of interdisciplinary education, access and barriers to interdisciplinary education, and roadblocks preventing wider adoption of interdisciplinary instruction. Section 5 considers existing and needed supports for practitioners as well as existing and needed policies and structures in schools and districts to widen the current reach of interdisciplinary education.

2. Definition and Goals of Interdisciplinary Education

2.1 Defining Interdisciplinary Education

The existing literature on interdisciplinary education does not include a consensus definition of the term. However, most definitions held several characteristics in common, including disciplines as a foundation of learning, involvement of two or more disciplines, and explicit integration of disciplines for a purpose most often identified as answering a complex question or solving a complex problem. Results from the landscape analysis confirmed that multiple definitions of interdisciplinary education exist among those actively working in the field of education. Although responses from researchers were not identical, these characteristics and other similarities appear across them. Among practitioners, definitions of interdisciplinary education varied more widely.

2.1.1 Researcher and Practitioner Perspectives

Researchers did not have a single, unified definition of interdisciplinary education but were consistent in identification of several key characteristics. Even among people using the term consistently, its operationalization was often different. Edward Geary, Director of Science, Mathematics, and Technology Education at Western Washington University, noted, “You can get lost in the definitions of these things and how people apply them because no matter what your own definition is, and even if somebody says, ‘Oh yes, interdisciplinary or transdisciplinary or multidisciplinary, they still have their own understanding of what that really means.’”

Even so, researchers identified the following key characteristics of interdisciplinary education: engaging two or more disciplines, making authentic or real-world connections, and having a clear purpose to integrate disciplines. Researchers were adamant disciplines remain intact so that students approach a topic of study with disciplinary grounding. Nell Duke, Professor in the College of Education at University of Michigan, commented that interdisciplinary education is “a salad, not a soup.” Put another way, the whole is greater than the sum of the parts, but one can still identify component parts (i.e., the disciplines). She added the importance of “respecting the integrity of the disciplinary practices and norms” and that interdisciplinary learning should not be a replacement for disciplinary learning. Instead, students require foundational knowledge of disciplines to address questions or problems they are

studying in a given context. One criticism often leveled at interdisciplinary learning is that it loses the rigor of disciplinary learning. Yet, respondents interviewed were clear that quality interdisciplinary instruction is grounded in disciplines, even though the literature at large also acknowledges other foundations including socio-political frameworks as well as traditional, lay, and Indigenous forms of knowledge.

Most researchers further indicated that interdisciplinary education needs authentic connections to students' lives. Authentic connections can take multiple forms, but the question or problem being studied must exist in the real world and be relevant to students. Jennifer Lutzenberger Phillips, Director of Learning and Teaching at ConnectED: The National Center for College and Career, noted that its model of interdisciplinary teaching and learning has "authenticity as the critical foundation" that is operationalized through an industry or career pathway connection. The approach in the International Baccalaureate (IB) Middle Years Programme (MYP) is founded on addressing a concrete problem relevant to students. Nat Erbes, Curriculum Manager for IB MYP, stated, "So much of the MYP and the IB is about inquiry-based learning where students are learning what they're learning so that they can address a real-world issue, so that they can see the relevance in what they're doing, and interdisciplinary learning lives and breathes there." Because complex and compelling problems in the real world are not solvable by a single discipline, interdisciplinary approaches arise out of necessity. Echoing John Dewey who argued that discipline-based learning in schools arbitrarily separate subject areas and obscure students' understanding of real-world phenomena, Ron Berger, Chief Academic Officer of EL Education, and Paul Sutton, Professor of Education at Pacific Lutheran University both noted that education should mimic the real world by combining skills, concepts, and content from different disciplines that are needed.

The final commonly cited characteristic is the need for interdisciplinary education to have a clear purpose or goal. Disciplines are integrated in service of an issue, problem, or question that requires multiple disciplines. Elyse Eidman-Aadahl, Executive Director of National Writing Project, said the disciplines have "to be pointed at something" such as a "wicked problem." Nat Erbes stated that interdisciplinary learning is "a highly purposeful integration of nuanced knowledge or perspectives" from multiple disciplines. He noted, "You're not just going to integrate biology and English literature because you fancy it; you're going to integrate them for a reason. And that reason is going to be the problem facing you." The sense of purpose that is critical to interdisciplinary learning is similar to what has been described in interdisciplinary research—knowledge and lenses from multiple disciplines are leveraged to achieve a more complex understanding, solution, or innovation.

> *Interdisciplinary education is "authentic in the sense that if you're integrating, it's not integrating for the sake of integrating; it's integrating when there's a purpose or a goal in mind. And I think that purpose and goal is oftentimes making the learning authentic to students."*
>
> — Charlene Czerniak

Although nearly all respondents described the need for two or more disciplines, an authentic connection, and a clear purpose to integrate multiple disciplines, the exact process of integration was discussed less frequently. Veronica Boix Mansilla, Principal Investigator at Project Zero at Harvard University, noted this process of integration—the "magical point of integration"—as the greatest puzzle

in interdisciplinary education. Despite the challenge in defining it, it is the "core to discovery in science" or to "creation of new projects" and is the point where novelty and deeper understanding emerge. In addition to purpose and authentic grounding in multiple disciplines, Boix Mansilla argued that interdisciplinary education must be truly "integrative."

Practitioner perspectives on the definition of interdisciplinary education varied. Multiple practitioners echoed researcher definitions, including inclusion of multiple subjects or disciplines, grounding in rigorous disciplinary standards, and use of a problem- or project-focused application relevant to students. One middle school teacher noted that interdisciplinary education is "blending the core subjects currently taught in separate silos… through project-based lessons and activities within the classroom." She noted that students should be made explicitly aware of disciplinary concepts as they encounter them: "Whenever you can, in every lesson, you should help the students notice inter-related concepts. For example, if we are launching rockets in our CTE class, there will be mathematical components. When we launch rockets we not only design rockets, we calculate acceleration due to gravity, or falling velocity. I bring math in purposefully. I don't say, 'This is a math lesson.' But we have to do the math to understand the concept of a rocket's motion."

Others were more pragmatic in their definitions, linking interdisciplinary education to disciplinary standards and thinking about how lesson plans may look in their classrooms. One practitioner described interdisciplinary education as standards across disciplines being aligned or addressed in a single lesson. Another described it as a "blending of subjects" that can engage students in something they are curious about. Yet another described interdisciplinary education as collaborative lesson planning with other core-subject teachers and identifying enrichment activities that would enhance instruction across all subjects. Similar to researchers, district leaders recognized the need for relevance to students' lives and facilitated creating or implementing curriculum using local case studies on issues such as environmental and community health and advocacy. They cited this approach as a way to draw students in to what they are learning and in a way that naturally integrates multiple disciplines.

2.1.2 Interdisciplinary Education and Related Terms

Multiple respondents were currently involved with or had previously published definitions and characterized the various educational approaches, including Veronica Boix Mansilla, Kelly Day, Nat Erbes, Robin Julian, Julie Thompson Klein, Louie Lopez, and David Moss. These individuals confirmed distinctions often made among multidisciplinary, interdisciplinary, and transdisciplinary education. In addition to the integration continuums as described in the literature review, two additional metaphors were used to describe the relationship among the educational approaches.

- Nat Erbes used a series of buckets to indicate disciplines. Going deeply into a single bucket represents disciplinary study in which the student stays within one bucket, sometimes at the surface and sometimes deep into it, but always within one bucket. Interdisciplinary learning is a combination of the buckets, in which the student goes deeply into a single bucket but then surfaces and meaningfully engages with another bucket. Transdisciplinary knowledge can be thought of as one large bucket containing the mixed-up knowledge from all other buckets. However, in transdisciplinary learning, students often draw upon the surface level of knowledge.
- Kelly Day, Einstein Fellow and member of Interagency Working Group on Convergence Education, described the relationship among terms using a scoop of ice cream to represent each discipline and provided an example of each term in relation to a classroom unit on Egypt. Disciplinary education is similar to a single scoop of ice cream; multidisciplinary education is having multiple scoops of ice cream, each with their distinct flavor. Interdisciplinary education creates a sundae with a slight mixing of flavors and added sprinkles; and transdisciplinary education would be a complete mixing of ice cream flavors into a milkshake.

Term	*Classroom example (Kelly Day)*
Multidisciplinary	Egyptian unit in which students learn about Egyptian math in math, the history of Egypt in social studies, and the embalming process in science
Interdisciplinary	Lesson or unit that requires both science and math to solve the problem, for example, calculating the embalming process, decomposition times, or the age of mummies
Transdisciplinary	Pressing problem that requires students to use multiple lenses to solve, such as "If we want to preserve something for the rest of society, how would we do it?"

Although several researchers had thought carefully about the meaning of each term, most respondents were not concerned with differences between interdisciplinary education and other related terms and used them interchangeably. David Moss, Professor of Education at University of Connecticut, noted, "In many ways I think outside of the literature base and some very narrow conference sessions… a lot of these terms in the real world have operational synonyms." Interdisciplinary education then is often considered a "catchall" term, encompassing multiple approaches if they include more than one discipline. Practitioners confirmed that at an operational level in classrooms, it was difficult to distinguish between the terms, particularly interdisciplinary and transdisciplinary education. They tended to use a variety of terms and did not prioritize or privilege the specific term "interdisciplinary" education. Several practitioners used the term "cross-curricular," "integrated," and "cross-cutting concepts."

Integrated studies. Like interdisciplinary education, the term "integrated studies" had mixed use and understanding among researchers and practitioners. Several practitioners mentioned that their district or state tended to use the term "integrated" over "interdisciplinary." This was the case in districts in Michigan and North Carolina. Some instead used the two terms synonymously, but others distinguished

them, with "interdisciplinary" meaning between two disciplines and "integrated" a broader concept. Leslie Eaves noted that integrated is "not only integrating content but integrating skills, integrating habits of mind, integrating mindsets, bringing all that together into the courses." Nell Duke agreed, distinguishing "interdisciplinary"—in which disciplines are still recognizable and distinct—from "integrated"—in which integrity of disciplines is not prominent or present. She provided two examples: "And so in an interdisciplinary model, the integrity of the individual domains is still evident in the instruction that deals with the engagement of the inter-relationship of those domains or disciplines. Whereas in integrated instruction, you can very easily lose the sort of integrity of the discipline that you're talking about. So, it can be hard to recognize the central tenants of that particular discipline." In this sense, integrated studies or integrated education is more consistent with transdisciplinary education because it goes beyond disciplinary boundaries.

2.1.3 Preference for Terms

Preference for the term "interdisciplinary" was decidedly mixed. Some respondents reported using "interdisciplinary," others preferred "integrated," others professed no preference for terms, and still others cautioned against using the term interdisciplinary education at all. Two notable exceptions in organizations or agencies embracing the term "interdisciplinary" emerged. The first instance is IB, which has committed to an interdisciplinary learning approach, particularly in the MYP and to a more limited extent in the Diploma Programme. IB recently commissioned a review of interdisciplinary approaches in current IB curriculum, and in 2021, released a revised *Interdisciplinary Teaching and Learning in the MYP Guide* and accompanying Teacher Support Materials. The guide provides schools and teachers a framework to structure meaningful interdisciplinary inquiry, including planning, delivering, and assessing interdisciplinary units. All students are expected to participate in one interdisciplinary unit per year as part of the MYP. In addition, IB published frameworks and guides for interdisciplinary learning as part of the World Studies Extended Essay in the Diploma Programme in 2016. According to Robin Julian, IB Curriculum Manager, IB is currently developing an expanded, enhanced framework and guidance for the interdisciplinary pathway for the Extended Essay that will be published in 2025. The second instance is the Federal Coordination in STEM Education Interagency Working Group on Convergence Education (IWG-C), co-chaired by Louie Lopez, U.S. Department of Defense STEM Education Director, that has committed to convergence education and the closely related transdisciplinary education, to align with the Federal STEM Education Strategic Plan as outlined in *Charting a Course for Success: America's Strategy for STEM Education.*[1] The IWG-C recently conducted a substantive literature review on convergence education in the K–20 space towards the development of a convergence education definition and further understanding transdisciplinary learning in STEM education. IWG-C efforts are centered around developing, refining, and promoting a flexible and adaptable "Pathways to Convergence" framework that can be leveraged by educators, stakeholders, and federal agencies. While still under development, the framework will emphasize the need for input from both federal agencies and external stakeholders and is designed to be iterative and to evolve over time.

[1] See https://www.energy.gov/sites/default/files/2019/05/f62/STEM-Education-Strategic-Plan-2018.pdf.

2.2 Goals of Interdisciplinary Education

Although the term "interdisciplinary education" has been used in the field of education for many decades, multiple researchers and practitioners strongly cautioned against focusing on interdisciplinary education itself as a goal or strategy. Respondents offered multiple reasons for this perspective. Several respondents described the fatigue, particularly among educators, that can occur with terms being "branded." Paul Sutton noted that there is a "kind of disease in educational circles that when we come up with a slightly new idea, we have to rebrand it by calling it something different, but it's essentially 90% of what we were doing before." He noted that practitioners are often skeptical when the next new education "thing" emerges and that branding interdisciplinary education might encounter resistance. Others contended focusing on the term and discriminating among closely related terms (e.g., multidisciplinary, transdisciplinary, integrated) may be off-putting to practitioners. Elyse Eidman-Aadahl cautioned that the goal of interdisciplinary education could be "derailed by too much attention to the nuances between terms, because then all of a sudden, it feels too academic and too beyond me, when the real thing is, we can't really look at this problem unless we can actually draw on what the different disciplines have to say and how they would approach it."

Many others shared the sentiment that focusing on interdisciplinary education as the goal itself is misplaced. Instead, interdisciplinary education should be considered an approach, with the goal being authentic learning. For instance, Mike Gallagher, the Oakland MiSTEM Network Director for Oakland Schools, Michigan, noted, "I think it [interdisciplinary education] would be a characteristic of something more important, and that would be learning that has an authentic nature to it. So, authentic problem-solving or real-world research that especially might connect to student's lives and communities or really legitimate production of something. Sometimes, not always, there might be a need for multiple disciplines." Similarly, Veronica Boix Mansilla acknowledged that she once was very concerned with precise definitions of various approaches, including multidisciplinary, interdisciplinary, and transdisciplinary. However, her thinking has evolved such that she now prioritizes what is "at the heart" of that interdisciplinary work, which is not interdisciplinarity. She notes, "That's one misconception that I think we have a lot in schools. We're doing interdisciplinarity because of it being interdisciplinary. I think that we need to move the conversation into we're doing interdisciplinary work because it supports a larger question or the resolution of a problem." Similarly, Ron Berger argued that the degree of interdisciplinarity or the presence of multiple disciplines was not important; instead, what matters is the "quality and depth of the learning experience for kids." Stephen Pruitt confirmed, saying that the term may distract from focusing on what students are trying to do and the tools they are leveraging to do them, regardless of the label. Mike Gallagher summarized these viewpoints succinctly:

> Rather than research interdisciplinary or promote disciplinary, what I think we should do is put our focus on the impact we're trying to make for students. For that, it's an evolving sense of identity where they feel like they can have mastery and they have an affinity for various disciplines; they feel that they could aspire to participate professionally in those disciplines down the road. What makes that happen is not necessarily an interdisciplinary achievement; it's really more I think the authentic or real-world problem-solving coupled with a focus on deep content, deep disciplinary knowledge, as well.

Although it was widely recognized that interdisciplinary approaches can be beneficial, it is just one approach in service of the goal of authentic student learning.

Definition and Goals of Interdisciplinary Education: Summary of Key Findings

- Most researchers defined interdisciplinary education using common characteristics, including engaging two or more recognizable disciplines; making authentic or real-world connections; and having a clear purpose to integrate disciplines.
- Practitioner perspectives on the definition of interdisciplinary education were variable, with some practitioners defining interdisciplinary education similarly to researchers and others using multiple terms interchangeably such as interdisciplinary, integrated, transdisciplinary, and cross-curricular. Many aligned it with real-world applications that are relevant to students' lives.
- Multiple respondents cautioned that focusing on interdisciplinary education as the goal itself is misplaced. Instead, interdisciplinary education should be considered an approach, with the goal being authentic learning.

3. Practicing Interdisciplinary Education

3.1 Interdisciplinary Education Approaches and Examples

Researchers mentioned a variety of approaches to interdisciplinary education. Each one aims to increase student motivation and engagement as well as connect student learning to its real-life application. Project-based learning and problem-based learning received the most attention. Other approaches mentioned included thematic learning, competency-based education, career and technical education (CTE), and service- or work-based learning. Practitioners interviewed had experience with project- and problem-based learning, thematic learning, and/or CTE.

3.1.1 Project-Based Learning

Many cited project- or problem-based learning as an exemplary approach to interdisciplinary education because it begins with a pressing question or issue that must be solved. Paul Sutton noted, "PBL is a manifestation of a belief that interdisciplinary education is how kids are best educated. It's our best answer to that question: what does interdisciplinary learning look like?" Veronica Boix Mansilla explained, "Project-based learning is phenomenal because it is about beginning with the issue. It's beginning with the issue and then figuring out what are the disciplines that will help us here. And I think that distinction between what's the question and what's the issue that we're going to solve, and what are the disciplines that can help us here, I think is really important."

Some researchers noted that project- or problem-based learning is not necessarily inherently interdisciplinary and must be done well to be impactful for students. Leslie Eaves encourages teachers who are making the shift to project-based learning to get used to implementing it within one discipline in their classroom first before trying to integrate multiple disciplines into the use of the method. Ron

Berger advised, "I think it's useful to use a rigorous standard for what we're talking about with project-based learning. And I think in lieu of other ones, you could use the PBLWorks Gold Standard Project-Based Learning one… It's similar to High Tech High's, to EL's, to Big Picture's, to New Tech's." Stephen Pruitt contended, "I think PBL is probably one of the better ones [approaches to interdisciplinary education], but even with that, it comes down to how well the training was done to really effectively implement it… The instructional strategy should still be centralized in what is a student trying to solve and what tools do they have to solve it?"

Quality project- and problem-based learning includes multifaceted questions and real-world problems. Veronica Boix Mansilla, Nat Erbes, and Paul Sutton explained how project- and problem-based learning naturally lead to opportunities for interdisciplinary learning. Boix Mansilla provided an example of a multifaceted question: "How do musical instruments produce beautiful sound?... Eventually we'll probably need to call in the physicist. And then you have something about music and beauty. So, probably would need the artist and musician as well… So, what I notice is there's a pattern there in this crafting of the problem or crafting of the question that in the very framing also helps. It's a little bit like dissertation questions, right? The framing really invites more precise engagement with the issue." Sutton further noted, "We demand of them [students] that they try to figure out complex, real-world problems, and then we give them all the tools we possibly can to help them solve those problems… And if we tack towards those principles, all of a sudden, how we have constructed content areas in a high school completely… erode. Because that project doesn't stay within the confines of one classroom. Those kids have to go out and they have to investigate that problem through different disciplinary lenses. And it happens simultaneously. So, that's what I mean by PBL is the answer to the question, 'What does interdisciplinary learning look like?'"

Project- and problem-based learning was identified as an approach that could be used at all grade levels (Table 2), although it is more challenging to implement in higher grades, particularly in high school where collaboration is required across discipline-based departments. Project- and problem-based learning at the high school level was more common within charter school networks with flexibility in scheduling or public schools that temporarily implemented project- or problem-based learning through grants that were not sustained once funding and support ended.

Table 2. Examples of Interdisciplinary Education

Example	Description
Elementary grades	
Adding soccer goals to a soccer field	Third-, fourth-, and fifth-grade teachers collaborated to facilitate the student-led project-based learning to **build soccer goals on the school playground**. Students used math skills to map out the perimeter and area of the field as well as science and engineering to determine materials needed to build the goals and how to secure them together. Students shopped for materials, priced them out, and were given a budget. They also met with community members who were engineers at Dow to ask questions about the design of the soccer goals. Students built the goals, sprayed the fields, and set up the goals. (Shelby Watts)

Table 2. Examples of Interdisciplinary Education — Continued

Example	Description
Middle grades	
Health in Our Hands	Health in Our Hands (https://hioh.education/), produced by Michigan State University, is a "place-based, problem-solving, standards-aligned curriculum." It is **a community-based module for sixth grade that looks at critical community health concerns such as diabetes**. Students learned life science while also looking at the community in terms of social determinants of health and risk for disease, including walkability, whether students are let outside for exercise, what lunches are like, and how adults in the community are educated about diabetes. A conference was then held with notable people from the community attending the sessions presented by students. (Mike Gallagher)
Soap-making	One project conducted with eighth-grade students was **making soap**. They talked about chemistry and made the soap in science class. They also created a business plan to sell their soap in math class, and in English class, they created advertisements for their soap. In history class, they conducted background research on soap-making. The art teacher helped them design packaging for the soap. Students then presented their final products at a fair. (Tameka Woodruff)
High school	
Rebuilding the coastal wall of a traditional Hawaiian fishpond	At a small independent high school in Hawaii that integrates science, technology, engineering, and mathematics learning with Hawaiian cultural practice through competency-based education, the principal encourages her students to **pursue design challenges related to their career goals and the cultural practice[s] that interest them.** A student interested in material science engineering is conducting experiments with different types of materials that could be used to rebuild the coastal wall of a traditional Hawaiian fishpond that is deteriorating. The challenge is to find an ideal material that can withstand daily beating from the ocean waves as well as allow the permeation of the water into the fishpond, since coastal fishponds contain brackish water. (Toni Kaui)
Moving vaccines across rural Africa	A biochemistry class at Sammamish High School which had received a grant for project-based learning "was tasked with figuring out **how to move vaccines across rural Africa**. And the assessment was to do a presentation at the Gates Foundation." Teachers and students realized they not only needed a thorough understanding of the chemical makeup of particular vaccines and the temperatures at which they should be shipped but also geography, such as roads and endpoint infrastructure. They also had to ask, "What are the hospital resources?" and "What do the community centers look like?" (Paul Sutton)
All grades	
Topical courses using phenomenon-based learning	In Finland each semester, students of every grade level take a course as part of their "**phenomenon-based learning.**" For instance, in fifth grade, a course titled "Café" involved setting up a café, including marketing, cooking, and accounting. In high school, course titles included "Climate Change" or "Airplanes." Each course was student-led and could vary widely from semester to semester in terms of what was studied or explored. For example, students in the "Airplanes" class could ask, "How do airplanes stay in the air?" and then move to "What is the environmental impact of airplanes?" or "What is the history of flight?" (Kelly Day)

3.1.2 Other Interdisciplinary Approaches

Thematic integration or thematic learning has a long heritage and is an interdisciplinary approach often implemented at the elementary level with one teacher who manages the days' worth of instruction. Teachers integrate math, literacy, and science experiences all within thematic units. As one district leader described, "You choose a theme and then that becomes your intersectionality for all of your disciplines." For example, students study rainforests, bringing in history and economy of the rainforest, products of the rainforest, and its ecosystems and flora and fauna. The district leader distinguished thematic learning from project-based learning in that it does not necessarily result in a substantial product or project for an outside audience.

Competency-based education was cited by several researchers as an approach that encourages and enables interdisciplinary education. Competencies, when well crafted, can often encompass multiple disciplines. A lot of standards are broad, cross-competency, and transferable in the sense that they could be learned in one area but applied in any area. A large part of competency-based education is completing projects that include performance-based assessments, according to Eliot Levine of the Aurora Institute. For example, at a competency-based school in New York, competencies are categorized into ten broad buckets considered inherently cross-disciplinary. Every teacher, in every subject, uses Shared Outcomes that integrate "21st-century skills" needed to be successful in college, career, and beyond: Argue, Be Precise, Collaborate, Communicate, Conclude, Create, Discern, Innovate, Investigate, and Plan.

CTE classes have also been a vehicle for implementing interdisciplinary education in schools and preparing students for future careers. Leslie Eaves noted, "Just in the very nature of the course, it is interdisciplinary, because kids … have to read technical literature; in many cases they have to do math. It runs the gamut for more vocational programs like auto mechanics and construction to more high-tech programs like biotechnology and engineering and all things in between. Even though it is a single course, the course usually, by nature the way that it's written, is interdisciplinary in its approach." For instance, in Pennsylvania, CTE standards were matched with state math standards; something similar was done in Alabama where the middle or high school math standard that corresponds to various automotive technology standards was identified. This helps teachers be aware of the problems that connect back to math standards and how to help students make connections between concepts they learn in math class and their real-world applications.

Internships and service- or work-based learning provide a unique hands-on opportunity for students to integrate disciplines while applying their knowledge and skills to real work. Ron Berger cited opportunities for students to conduct field work or research or for schools to bring in outside experts: "Any one of those things that breaks the barrier of school to real life makes things interdisciplinary." Eliot Levine stressed that students engage in many activities outside the school building that have the potential to fulfill academic standards and are interdisciplinary in nature. For example, internships are a regular part of students' weekly schedules at Big Picture Learning schools. The schools are designed for students to spend 2 days a week for the entire 4 years of high school outside the school doing internships.

Unnamed interdisciplinary learning. Ron Berger alluded to "unnamed" interdisciplinary learning that is already occurring in regular school classes and activities, such as students researching and creating a report for science class using English skills. Many extracurricular activities such as band, orchestra, drama, model United Nations, debate club, school newspaper, and student government are interdisciplinary. These "unnamed" interdisciplinary experiences are often "the most powerful experiences of high school" for students because they resemble real life. "Because you're actually putting out a paper, you're putting on a performance, you're putting on a play, you're engaging in a debate, like in real life, you're producing something. And when you produce something, it's always going to be interdisciplinary." Even though these experiences are not labeled as interdisciplinary, they are interdisciplinary learning and powerful experiences for students.

3.1.3 Scope and Scale of Interdisciplinary Education

The scope of the term "interdisciplinary education" is broad and can span full courses to individual units to single lessons or even components of a lesson. For instance, the Ethnic Studies course in San Francisco Unified School District (SFUSD) is an example of a full interdisciplinary course. As described by Nikhil Laud, Ethnic Studies Coordinator for SFUSD, students in the Ethnic Studies course draw upon "elements of maybe sociology, possibly psychology, possibly legal theory" and history in the analysis of issues relevant to them. Similarly, IB students engage in an entire interdisciplinary unit at least once per year during the MYP.

Interdisciplinary education can also occur on a smaller scale. Mike Gallagher noted that the Next Generation Science Standards has mathematics "baked into it" through analyzing and using data, computational thinking, and computer science. It has literacy included through argumentation, writing, and scientific explanation. The Next Generation Science Standards includes these as the tools of conducting science, but points throughout science instruction are also interdisciplinary in nature. In addition, interdisciplinary approaches can be contained in smaller lessons within a larger unit. Veronica Boix Mansilla described a biology teacher who realized students in his class were not good at observation which was a necessary component of the biology investigation. Having exhausted his knowledge of how to teach the art of observation, he decided to engage the art teacher who had multiple other approaches to instruction. The art teacher offered four lessons on deep observation that enhanced the observational tools of biology students through the craft of the artist. Boix Mansilla argues that these are small, but very high-quality moments, of interdisciplinary learning.

3.2 Interdisciplinary Education as Equity-Centered Teaching

The foundation of equity-centered teaching is the need to recognize the distinct backgrounds of students in designing academic programming to ensure that all students have opportunities to learn and realize their full potential, including across race and ethnicity, income level, and English learner or disability status.

Interdisciplinary education is aligned with, and may even be essential for, equity-centered teaching. The starting point for interdisciplinary education—a complex, authentic, real-world problem, question,

or issue—provides a meaningful connection to students who may not immediately see the relevance of traditional disciplines to their lives. Veronica Boix Mansilla noted, "We owe it to kids who are born in the context of less privilege to really tackle the very issues that are important to them and to their communities in powerful interdisciplinary ways." Interdisciplinary projects engage students in authentic problems and issues, offering opportunities for low-income students or students facing barriers a way to make connections between school and their life experiences. Ron Berger concurred, "The more we stick with a strict old school traditional division of disciplines, the more artificial school is, and the more artificial it is, the more it becomes a game of who knows how to play school well. And one's ability to play school well is deeply dependent on the parents you have and the conditions you grew up in….. When the learning connects to life, it gives an entry place for a much broader catchment of kids than when it's playing the game of disciplinary school. So I do think of it as an equity imperative." He further noted that when school connects to real life, kids that grow up with life skills can shine at school and be valued for their contributions. In turn, they begin to see the relevance of school for their future, thereby jumpstarting a virtuous cycle.

Interdisciplinary education provides an opportunity for students to "see themselves" in the material and see themselves as contributors. Multiple respondents, including Beth Allan and David Moss argued that interdisciplinary education can be inclusive if it contains phenomena that are culturally relevant to students. Too often traditional units lack culturally relevant content. Students must see themselves represented to increase the likelihood of engagement and success. Interdisciplinary approaches allow students who may not be eager contributors in the traditional classroom to contribute in meaningful ways and see themselves as contributors. They tend to get invested in the learning and engaged in the project, learning the disciplinary content along the way. One district leader recounted how third-grade students in her district completed an arts-based unit in which they adapted a book into a play: "There were a number of different activities with it, and as we went through it, you didn't see who was the struggling reader, and who was the English learner, and those kinds of things. Everybody was involved, and everybody was learning. So to me, it really went along with that equity role because everybody was provided an opportunity to be successful and to grow. I see some schools where it's, 'No, no, no, no. We're not going to do that, we have to focus on reading and math.' But when I focused on that interdisciplinary approach, the reading and math came along. And so those students had the opportunity to do these greater things that you often see ... the higher achieving schools do. These students had the chance to do it, too, and did it very successfully, and grew."

A recent article on the effect of student completion of the Ethnic Studies course in SFUSD provides some evidence for the benefits of real-world authentic connections in interdisciplinary instruction (Bonilla et al., 2021). Authors examined long-term effects of participating in the course for students who were at risk of not completing high school. They found positive long-term high school and postsecondary outcomes, confirming previous anecdotal evidence of positive effects of engaging with the interdisciplinary course that had cultural relevance and real-world application for students. Eliot Levine noted that positive outcomes may be associated with interdisciplinary learning because it is engaging: "Students often find it much more interesting. And when you find it more interesting, you're more likely to work hard. And when you're working hard, you're more likely to meet your own learning goals as well

as the school's and society's learning goals for you." While these are good outcomes for all students, they are particularly helpful for traditionally underserved students.

To keep equity at the center, interdisciplinary instruction must provide scaffolding to students who need it. Jennifer Lutzenberger Phillips cautioned that "kids who are not yet at grade level stand to lose a lot in interdisciplinary and project-based learning" unless teachers ensure that students have appropriate scaffolds to make connections within and beyond the immediate project as well as engage in the disciplinary content. It might not be initially apparent that students are not making necessary learning gains because all students tend to be engaged and enjoy interdisciplinary learning and project-based learning. However, she emphasized how critical attending to equity and students' ability to make connections is: "The work that we [ConnectED] do so that from the start, your interdisciplinary design is interdisciplinary design for equitable access.… We have seen that unless teachers and leaders know and work with those realities [students' readiness to make connections], you end up reproducing all of the current limitations in the single subject."

Interdisciplinary approaches further reflect an equity-centered approach in the sense that they provide experience and connections to real-world applications within the school day. These connections can sometimes be lost if students are responsible for making them at home. Leslie Eaves noted, "We know that kids who come in from high poverty situations … they lack experiences, just for the fact that they don't have the economic choices that, say, somebody with a middle-class job has. That limits travel. That limits going to museums. That limits a whole bunch of stuff.… To me, classrooms need to provide that atmosphere. When you teach subjects where kids are seeing the interconnection between the subjects, we're kind of building those experiences within the school. Why project-based learning is, when we actually give kids a deep learning experience that they can't necessarily get at home and they can't necessarily get on their own, we're providing that space within the school to do that. If we do that for every kid and provide that for each student, then we're supporting equity."

Deeply equity-centered teaching may create tensions with district administration. Recounting experiences in Sammamish schools, Paul Sutton described tensions that may result if interdisciplinary and project- or problem-based approaches are implemented in a truly equity-centered way. The tension is that "PBL philosophically, in a pure form, pushes back against all of the chronically inequitable structures of the school district. School districts are built on an idea of commonness across schools and across departments. And PBL, if it's done well, does not do that. If you do PBL in one high school, the specifics of it are going to look different than at another high school, especially if they're different student demographics, because the whole nature of PBL is responsive to student interest and what's going on out in the community and all of that. And so, it has to stay flexible and adaptive and responsive. It eschews any kind of standardization." Because most districts, and the education system more broadly, is built on a foundation of standardization, it is challenging for student-centered approaches like interdisciplinary education and project- or problem-based learning to establish a firm foothold in public schools. Sutton noted, "It's just philosophically, diametrically, opposed to how school districts have been designed and structured over time."

Practicing Interdisciplinary Education: Summary of Key Findings

- Project-based learning was cited often as an exemplary approach to interdisciplinary education because it focuses on a problem to be solved that often has real-world relevance for students.
- Other educational approaches described as consistent with interdisciplinary education include career and technical education, work-based learning, and competency-based education.
- With the starting point of an authentic, real-world problem or issue, interdisciplinary education provides a meaningful connection to students who may not immediately see the relevance of traditional disciplines to their lives. In this way, interdisciplinary education is aligned with, and may even be essential for, equity-centered teaching.
- Interdisciplinary education can be inclusive by allowing students to see themselves in the material and see themselves as contributors, but careful attention should be paid to the scaffolding needed to make this instructional approach beneficial for all students, regardless of their beginning academic proficiency.

4. Current Reach of Interdisciplinary Education

Respondents agreed that interdisciplinary education is not widespread in U.S. education. It may exist in pockets, but it is not a common approach in education. This finding is true, regardless of region, locale, school level and school type. As Eliot Levine summarized, “It's more the exception than the rule, and even schools that do some interdisciplinary education may not do it intensively.” Furthermore, where it is offered, it is often unequally implemented, with schools having high-performing and wealthy students offering this type of innovative approach more often than schools with low-performing and low-income students. Given limited current reach, respondents recounted multiple existing roadblocks to current implementation and wider adoption in the future.

Limited reach of interdisciplinary education. There was clear consensus among respondents on the limited reach of interdisciplinary education. According to Jennifer Lutzenberger Philips, philanthropic organizations have done promising work in this space, including the Hewlett Foundation and the Gates Foundation, but “it hasn’t had a very big impact on our nation’s schools as a system.” Single, isolated schools or networks of schools have demonstrated that it is possible to innovate and successfully engage interdisciplinary approaches. Similarly, practitioners noted that there are imaginative, creative, and dedicated teachers who see the value in authentic issues that demand multiple disciplines and take it upon themselves to engage their students in interdisciplinary learning. However, one noted, “I would say it's still not standard practice of teachers to do that.” Another teacher confirmed that there aren’t many opportunities to engage students in interdisciplinary education, noting that it is “limited, very limited.” Stephen Pruitt cautioned that a lot of “lip service” is being given to interdisciplinary approaches, but interdisciplinary education is not implemented very often. Where it is implemented, it is done so sporadically. He concluded, “Some of the better places, you're going to see where some CTE teachers, especially Agriculture teachers team teach with biology. You'll see some humanities integration between the English, language arts, and the history, but it's really not done as widespread as it needs to be.”

In fact, several respondents were concerned that things were moving in the wrong direction. As a Professor of Education who places students in schools for student teaching, David Moss concluded, "Sadly I would say interdisciplinary work is underrepresented. I would say the trend is moving against a growing number of schools adopting approaches or even considering trying some things out.… I'm not seeing a lot of interdisciplinary [education] in any of its forms out in the schools. I feel like right now we've taken a step backward towards the basics.… At the moment, it's almost invisible." Others noted that while certain conceptions of interdisciplinarity may be flourishing, including integration of literacy elements into content areas, integration between content areas is still a struggle, especially at the high school level and increasingly at the elementary level. One exception to this limited reach is the presence of "unnamed" interdisciplinary education occurring in schools. As noted in Section 3.1, many school activities are interdisciplinary in nature—for example, Speech and Debate and theater productions—but they are not labeled as interdisciplinary education.

4.1 Access and Barriers to Interdisciplinary Education

Access to interdisciplinary education is unequal across student and school populations, with private schools, wealthy public schools, and students with high scores on standardized tests given more access. Schools that have few (or no) curriculum requirements have the freedom to choose lessons, units, unit length, and all other facets of instruction. As noted by Nat Erbes, it is easiest to try interdisciplinary approaches in these types of education environments. Veronica Boix Mansilla agreed, noting that "private schools have more bandwidth, they have more freedom," and that this advantage allows them to offer interdisciplinary instruction to their students. IB schools and private schools, while theoretically open to students of all backgrounds, often serve students that come from privileged backgrounds.

Barriers for low-performing schools and students. On the other end of the spectrum, schools that have very little curricular autonomy will face major barriers to implementing interdisciplinary education in their classrooms. These schools often are low-performing schools that have district-imposed time requirements for each subject, furthering the disciplinary silos and making interdisciplinary instruction challenging. David Moss described this occurring across Connecticut: "Many of our wealthy districts have the luxury of performing and over-performing due to the amount of per-pupil spending, so they're, I think, more willing to stumble into areas of interdisciplinary work and other, let's call them more progressive approaches, where many of our larger urban centers, which have historically underperformed, they've jogged in just the other direction.… The traditional curriculum, that lack of autonomy that teachers might have diminishes the interdisciplinary work and then ironically underserves the kids. So there's

> *If you already work in a district where the test scores are good—which, just to be clear, means a wealthy district, and usually a white district—then you can bring in things like project-based learning, and STEAM work, and all these new ideas and interdisciplinary learning, because everyone feels like, we do fine, we can try new things with kids, because we're already on top of the heap. So there's a lot of flexibility in those districts. Those are the ones that come up with these creative ideas for new opportunities for kids because they're not under the gun. The districts that are struggling—and by struggling, you pick the city, they're struggling—the pressure is entirely to raise test scores.*
>
> — Ron Berger

connections here, where if you're doing well on the tests, you've got the privilege to think outside more traditional norms. So it's just backwards really."

Across the country, practitioners affirmed inequities in access to interdisciplinary education. One district leader noted that high-performing schools are "given free rein" to do interdisciplinary instruction because they are so high achieving. Even within schools, inequities are present. One educator said, "I know our honor students and our AP [Advanced Placement] classes, they are more likely to pull in information, lessons, field trips, the things that our regular or EC [Exceptional Children] kids or ESL [English as a Second Language] students never get to do. And I think that's because their classes are so focused on testing and just trying to meet the bare minimum."

One major barrier to access for interdisciplinary education, particularly for low-performing students, is the belief that they should not undertake real-world applications until they have demonstrated proficiency by memorizing certain facts or demonstrating certain skills. One district leader noted that, historically, interdisciplinary teaching, particularly at the secondary level, has been reserved for students who have already demonstrated a "base of knowledge" instead of being considered "a way of teaching the standards." This type of thinking is a major barrier for student access to authentic, enriching education.

> *I had a student who was dyslexic in fourth grade, severely dyslexic, had never been diagnosed to that point. And so of course, she developed all of those behaviors to avoid reading. She hated it. But when it came time for interdisciplinary units and hands-on kinds of things, she was right in there. And she was finding new material, and she was doing her research. And that was how we were getting her reading done. She needed the extra supports, but she wasn't battling us anymore because she really wanted to do it.*
>
> — School leader in New Mexico

Stephen Pruitt noted that many schools' responses to students who are behind academically is remediation, in which students are forced to spend even more time on the subject they are struggling with. He noted "the kids that have the most barriers to interdisciplinary [education] are the kids who struggle the most, which tend to be our most underrepresented.... If they are struggling on an assessment, and again, it goes back to the accountability, I'm a principal, I need those kids to pass that test." According to Stephen Pruitt, remediation rarely works. Instead, he argued for approaching remediation "from an interdisciplinary perspective to help students to understand how these connections are made" by providing students an opportunity to experience the concept rather than having to memorize words or facts. Ron Berger described it as a reverse equity issue: "The kids who most need access to richer learning experiences that connect to more real life are the kids that have the least of it." Allowing students to see that education can provide deep understanding of issues that matter to them and their communities is critical.

4.2 Existing Roadblocks to Wide Adoption

This section describes multiple roadblocks to adopting interdisciplinary education, with a focus on lack of systemic strategy, accountability policies, and educator capacity and preferences.

Lack of systemic approach. Countries that have had success with interdisciplinary approaches have implemented them on a national level. In the United States, many schools and school districts are

interested, but it is hard to consider all the factors that need to be aligned and changed in the absence of a systemic approach. Jennifer Lutzenberger Phillips noted, “There are all sorts of tiny little pieces of that larger puzzle that have to get tackled. But they get tackled piecemeal because we don't really have a lot of guidance or, I think, energy to deal with this in a systemic way. And that's a problem.” The result is that national reports are written but little follows in the way of implementation—an unsurprising result given that education is managed by state and local government. Countries such as Finland that have significant interdisciplinary education in their schools have a nationwide focus and implementation of a national strategy.

Focus on math and literacy instruction. For the majority of students in U.S. schools, the school day is broken into small segments devoted to single subjects. Many districts, particularly low-income districts, have time requirements such that all students spend a certain number of minutes on reading and math instruction. According to David Moss, the school day “is compartmentalized to the nth degree around the disciplines.” In some upper elementary grades, schools are even turning to a model in which there is one teacher for math, another for literacy, another for science, and so on. Teachers also often follow different curricula developed by different publishers with different models of instruction. Leslie Eaves noted, “Even in places where it would be easy for teachers to integrate, they're being handed curriculum that is siloed into these different areas and they don't feel like they have the freedom in order to do that.” Nell Duke echoed this concern, stating that there is “not even the potential for interdisciplinarity unless the teacher does it themselves, so I would say the landscape at K–2 is pretty discouraging right now.” Teachers are often nervous about fidelity to instructional time, which limits their willingness to incorporate interdisciplinary instruction that could detract from the time requirements.

Accountability system. Nearly every respondent described how the current accountability system in place in the United States works against interdisciplinary education. Ron Berger described how “the accountability system is working against you the entire time. Every superintendent, every principal, every teacher is being held accountable for one thing, and it's not what you're promoting [interdisciplinary education].” The accountability roadblock occurs in multiple ways. First, for many states, there are no science or social studies assessments until late elementary school, so there is little incentive for teachers to incorporate these subjects in their teaching. This is particularly true for schools under any type of accountability pressure, which tends to be schools serving low-income students. Kelly Day noted, “Taking any time outside of your class to teach something outside of your specific standards is actually seen as a liability to the school and not an asset. So it's not easily done and it's not encouraged.” Furthermore, teacher evaluations are increasingly tied to performance on standardized tests so teachers are disincentivized to focus on any subjects that are not tested. Teachers cannot move in the direction of interdisciplinary instruction if they are under threat of accountability measures. Leslie Eaves stated, “We can't innovate if teachers feel tied to that.” Eliminating this roadblock requires changing the way students are assessed or changing the value that is placed on assessments.

School structures and schedules. Schools are organized around disciplines, with teachers in self-contained classrooms and students switching courses. It is challenging for teachers to coordinate and work with each other to plan interdisciplinary units.

Educator disciplinary identities. Educators in secondary education are trained in their disciplines and are typically very comfortable teaching the value of their discipline to students. Asking teachers to go beyond their comfort zone, into substantive areas that they are either unfamiliar with or would require close collaboration with other teachers, is challenging. Ron Berger cautioned that a focus on interdisciplinary education "will make math teachers and science teachers mad, because they'll think, 'I don't want to teach other subjects.'" He argued that focusing on interdisciplinary instruction, as opposed to connecting classroom learning to real-life applications, would create resistance to the concept of interdisciplinary education.

Educator capacity. Teachers have incredible responsibilities and requirements without adding the challenge of learning, designing, and implementing a new instructional approach that might require new ways of teaching and collaborating and significant professional development. Mike Gallagher stated, "The change demand is huge on teachers right now." Even when teachers are excited and energized by the idea of engaging in interdisciplinary education, time is always a challenge. Teachers must find time to plan and collaborate with other teachers. One educator warned that a major roadblock was "having teachers that feel that they have time to do more and having teachers that understand what it takes.… So, trying to take some things off the plate to give teachers more energy to try new things and expand learning, so they can bring it to the students. The biggest roadblock is just trying to get the teachers on board because they're already overwhelmed." A second educator said, "Time in the day—there's not enough hours."

Current Reach of Interdisciplinary Education: Summary of Key Findings

- Interdisciplinary education approaches can be found in isolated pockets—within some schools and with some teachers—but the overall reach is extremely limited. Furthermore, several respondents noted that many schools are doubling down on single disciplinary instruction in the wake of the pandemic as a turn "back to basics."
- Interdisciplinary approaches are implemented very unevenly, with wealthier, higher performing districts more likely to implement them over lower income and lower performing districts; additionally, higher performing students are more likely to have opportunities for interdisciplinary learning than their lower performing peers.
- Respondents identified numerous roadblocks to a wide adoption of interdisciplinary approaches, primarily focusing on accountability and testing structures that govern so many instructional decisions in districts and schools. The capacity of educators (time and training) to pivot to a new instructional approach was a secondary concern.

5. Broadening the Reach of Interdisciplinary Education

Significant changes across multiple levels of the education system are necessary for interdisciplinary approaches to have a wide reach, from classroom-level resources for practitioners to organizational structures in schools to changes in the education system more broadly.

5.1 Supports for Practitioners

Few respondents could describe existing supports currently available to practitioners to implement interdisciplinary education; those that were cited, including some curricula or frameworks, were limited in reach. On the other hand, all respondents offered multiple supports or resources that are needed to support practitioners in implementing interdisciplinary instruction.

5.1.1 Existing Resources and Supports

Interdisciplinary curriculum. Respondents provided several examples of currently available interdisciplinary curricula that ranged in target age, disciplines, scope or scale of curriculum, and level of scriptedness. Resources include those from EL Education, Mi-STAR, Nell Duke's Great First Eight curriculum, and National Science Teacher Association resources, including Daily Do Sensemaking lessons (Table 3). Other curricular resources include those from the Solid State; Roots of Reading, Seeds of Science; and Concept-Oriented Reading Instruction. Respondents noted that most existing interdisciplinary resources are not well known to teachers outside of the districts where district (or state) leadership has dictated their use. And even when teachers do find freely available interdisciplinary resources, such as those available through National Science Teacher Association or OpenSciEd, they often are not aware of how to use them or where they fit best in their classrooms.

Providing existing, off-the-shelf interdisciplinary curriculum to teachers as a resource is one path to reaching many more students. For instance, EL Education shifted from a focus on deep implementation of experiential (often interdisciplinary) education models in a small number of schools to curriculum development and professional development that could be implemented more widely. The pivot from deep implementation to curriculum development started with the realization that most teachers were not beginning their teaching careers with the necessary training to design interdisciplinary units from scratch. A curriculum resource allowed more teachers an entrée into an interdisciplinary approach. Mike Gallagher argued that the most equity-centered path forward and the biggest lever to bring interdisciplinary education to the most students is "to systematize things with really strong, well-written curriculum and ample professional learning to help teachers enact it the way it's designed." However, multiple researchers noted that any interdisciplinary curriculum should be accompanied by substantial professional development support.

Table 3. Examples of Interdisciplinary Curriculum

Curriculum	Description	Current Use
EL Education	This K–8 open-source, free literacy curriculum is built on science and social studies content learning with character and citizenship targets. It is a scripted curriculum with optional extension components in which teachers can leverage their local contexts to focus on authentic, real-world connections.	Currently used in over 35 states and reaching over 500,000 students, including Charlotte, North Carolina; Wake County, North Carolina; Richmond, Virginia; Hamilton County, Tennessee; Des Moines Iowa; Boston, Massachusetts; Sunnyside District, Arizona; Detroit, Michigan; Oakland, California
Great First Eight	Developed by Nell Duke, this assets-based, all-day interdisciplinary curriculum centers equity for 0- to 8-year-old children and is intended for use in metropolitan school districts. Throughout all age and grade levels, the curriculum fosters children's engagement and agency; promotes diversity, inclusion, and equity; and prioritizes science, engineering, social studies, and transformative social-emotional learning as well as literacy and math. Most Great First Eight materials will be freely available online to support their widespread use in underresourced school settings.	Currently piloted in schools in Washington, DC, Michigan, and New York; anticipated release in Fall 2022 at greatfirsteight.org (www.nellkduke.org/curriculum)
Mi-STAR	This middle school curriculum, developed and written by researchers at Michigan Technological University (https://mi-star.mtu.edu/), is built around complex 21st-century problems. Each unit contains a challenge, then a series of lessons that address standards in science and engineering, and then students deploy the disciplinary knowledge to solve the problem. Local districts are beginning to adapt the curriculum to locally relevant problems.	Districts throughout Michigan
National Science Teacher Association, Daily Do Sensemaking Activities	Daily Dos are sensemaking tasks that teachers can use to engage their students in authentic, relevant science learning. Students actively try to figure out how the world works (science) or how to design solutions to problems (engineering) using science and engineering practices. Students share and evaluate ideas, give and receive critique, and reach consensus.	Freely available on the National Science Teacher Association (NSTA) website
National Science Teacher Association, District Professional Learning Packages	NSTA offers tailored packages of on-site presentations and workshops, online experiences, and books on popular topics—including three-dimensional instruction—for schools, districts, or states. Using a blended approach, NSTA combines a face-to-face component with additional online opportunities to extend learning. Implementing this approach promotes sustained change in classroom practice.	NSTA currently holds contracts with several major districts including in Denver, Colorado, and Los Angeles, California

Interdisciplinary frameworks. Aside from the frameworks developed by IB, respondents were not aware of existing interdisciplinary models or frameworks. IB MYP provides teachers Interdisciplinary Unit Guides, and IB professional development trains teachers in what the guides include. The IB MYP has a requirement that all MYP schools engage their students in at least one unit or module that is interdisciplinary every year. IB provides a template for designing the interdisciplinary unit that includes a process teachers follow to identify disciplines to integrate, identify questions the unit will address, collaboratively plan a unit that has disciplinary grounding from multiple disciplines, consider and articulate the purpose of integration (i.e., how the disciplines merge to address the problem under study), and create authentic tasks or assessments. Nat Erbes, Curriculum Manager for IB MYP, noted that although the framework IB developed is not "perfect," he was not aware of any other existing similar resources. A second interdisciplinary framework exists within the IB Diploma Programme's World Studies Extended Essay for student research projects or academic essays. The framework outlines the requirements for students to undertake an interdisciplinary study, including identifying an issue of contemporary global significance, identifying a local manifestation of the issue, developing a rationale for taking an interdisciplinary approach, and using the conceptual framework of two distinct Diploma Programme subjects. This framework offers students a continuation of interdisciplinary learning from the MYP.

5.1.2 Needed Resources and Supports

> *"We roll a lot downhill to teachers without necessarily giving them the support that they need as adult human beings and adult learners to actually get that work done."*
>
> — Jennifer Lutzenberger Phillips

Practicing interdisciplinary education requires a different approach to education than has typically been asked of teachers. Given the entrenched nature of disciplinary learning in the United States, most current teachers likely never learned themselves in an interdisciplinary manner. Shifting to this instructional approach requires substantial investment in resources and supports across multiple levels and systems, including preservice teacher training, in-service professional development, curricular resources, and support from school and district leadership. Table 4 outlines each of these needed resources and supports.

Table 4. Necessary Resources and Supports for Practitioners

Resource or Support	Description
Preservice teacher education	• Preservice teacher education should include methods courses where teachers gain **practice with designing interdisciplinary lessons** as well as clinical experiences implementing interdisciplinary units in classroom. • Future teachers need guidance on how to engage with family and community experts to build authentic, real-world connections. • A shift in the *role* of teachers is needed, as Julie Thompson Klein noted, from teacher as "sage on the stage" to "coach on the side," from rote learning to engagement. • Edward Geary and collaborators from universities across Washington State are working to modify education programs, courses, and clinical experiences for preservice teachers to include culturally relevant, interdisciplinary instructional skills. • Beth Allan is creating a new Bachelor of Science Education degree in integrated science, technology, engineering, and mathematics at University of Central Oklahoma that will focus on "interdisciplinary links around the cross-cutting concepts."

Table 4. Necessary Resources and Supports for Practitioners — Continued

Resource or Support	Description
Interdisciplinary curriculum, templates, and worked examples	• Teachers need **instructional materials that are compatible with current disciplinary structures**. One elementary school teacher noted the need for sample interdisciplinary projects or lessons that tie directly into the units that they are already teaching. • Some researchers cited the need for **interdisciplinary curriculum** as a priority because it provides an easy entry into interdisciplinary teaching. Ron Berger noted, "We can't reach teachers if we're starting with such a high bar, that you have to be a deep, talented project-based designer in order to be a teacher. It's terrific, but it's not every teacher can start that way or be that way. And so, scaffolding [curriculum] really helps." • Other researchers argued that **templates or models** are more compatible with interdisciplinary instruction. Paul Sutton said that teachers need support to "understand the pedagogical principles that are supporting the curriculum, and then we need to trust them that they'll create curriculum that best works for the specific students they're trying to serve." • Practitioners were eager for examples: "Teachers need a clear path to do it. They would need **good examples** to see if I were to do this, what would this look like? We don't have anything like that." A school leader suggested a "database, a storehouse, whatever, of **lessons that have worked**" would be a valuable resource. She noted, "Because I'm capable of taking that, and adapting it, and making it work for my students and my situation, if I at least have that place to start, sometimes that's what I need." • Any curriculum, template, or model needs clear **indicators of success** so that teachers know what they are aiming for with interdisciplinary instruction.
Video exemplars or experiential site visits	• Teachers need **video exemplars demonstrating the shift in teaching practice**, including "proof points in development" so they can see what is and is not effective interdisciplinary instruction. • David Moss noted the lack of "video case exemplars like, the 7-minute look-in on a middle school classroom, where a teacher is expertly asking and working with groups in ways that show interdisciplinary outcomes so that either a practicing even veteran teacher or young teacher could look and be like, 'I can do that.'" • Experiential site visits provide teachers and school leaders a view into interdisciplinary instruction occurring in schools in real time.
In-service professional development	• Teachers need in-service **professional development with coaches or teacher leaders** who have experience with interdisciplinary education design and implementation. • Leslie Eaves noted, "I think that teachers definitely need coaching—job-embedded coaching—where somebody sits down with them, they plan with them. They almost give them permission to try something and they support them through that process. That's expensive, but I do think it's worth the money if you have a well-trained coach or well-developed coach." Practitioners echoed this need. • **Curriculum-focused professional development** is necessary for teachers adopting new curricula. Ron Berger stated, "There is a need for more scaffolding for teachers that is a tremendous need to be met beyond just free resources online….. You really do need to have professional learning that goes along with the curriculum."

Table 4. Necessary Resources and Supports for Practitioners — Continued

Resource or Support	Description
Professional development with equity focus	• Professional development focused on **how to make interdisciplinary instruction effective and accessible to all students** is crucial. Providing adequate scaffolding for students requires training for teachers and additional adults in the classroom. • Teachers need professional development to know how to scaffold learning to students in an interdisciplinary environment, so that it is accessible to all students and not just those already proficient in the disciplinary standards. One district leader noted, "CTE gets it right a lot because they're so problem based, they're so hands on. They're getting in there, they're doing it and then they're applying terms to it."
School leadership support for teachers	• Teachers need **individual time to plan** to develop and implement interdisciplinary units. Paul Sutton suggested that instead of teaching six periods of a seven-period day, teachers should be teaching no more than four, noting that intensive human resources are required to buy teachers out of courses and bring more adults into school buildings. • Teachers need **common or collaborative planning time**, something that is challenging in secondary schools. As noted by Eliot Levine, "At the secondary level, doing deep interdisciplinary projects requires common planning time for teachers and more flexibility than traditional student groupings and bell schedules allow." • Teachers need **support to "fail forward"** by trying a new instructional approach, learning from mistakes, revising practices, and implementing it again. Nearly all practitioners reported that if the school leadership supports interdisciplinary education, it is much more likely to happen. One district leader in North Carolina noted, "If the leadership is supportive, … if it's something that is seen as valued by the leadership, then it's more likely to occur; they're more likely to set schedules that are conducive to planning and encourage teachers to talk and to risk take and to try." • Paul Sutton added, "They've [principals have] got to get into classrooms, they've got to work with teams of teachers.… It's all about making sure that your teachers can implement, can teach and implement really robust curriculum that helps students become more engaged democratic citizens."
District leadership support for teachers	• **District leaders need to understand how they can support and facilitate interdisciplinary learning** in their district's classrooms. Teachers confirmed that district support is necessary to really change the culture and practice within a school. • One teacher noted "the biggest support would be interest from the district level. That is what is needed at this point. I think we could access training, we could do a lot around it. We have highly qualified, educated people and teachers here. Until it is a priority, that's not going to change. It's not going to be reality." • Leslie Eaves argued that it is at the district central office level that clear support is needed and solidified: "Where I've seen it work well is the people within the district [central office] are working well together." In one North Carolina district, leaders attended the professional development teachers received, reviewed teachers' implementation plans, and visited classrooms to track and support the work. • Edward Geary noted the need "to focus also on preparing future administrators who can support and value those teachers." Because most states have certification requirements for administrators, this is a **potential policy lever** point to prepare future administrators to understand the pedagogy and value of interdisciplinary education.
District leadership support for school leaders	• District support must be provided to principals in ways that challenge the traditionally hierarchical relationship between school and district leadership. Paul Sutton cautioned, "In order for school leaders to do the supportive work they need to do with teachers, they also need a district that trusts their expertise and that trusts their experience to be able to manage a highly adaptive learning environment."

5.2 Changes to Educational Systems

Few existing policies or structures are in place that explicitly support interdisciplinary instruction. Instead, many respondents described existing policies or structures that could be changed to leverage support for interdisciplinary instruction as well as new policies or structures that are needed. Many also noted the need to target policies that affect large numbers of students, including policies around accountability, time on task, resources, and funding. In addition, given the interconnectedness of the education system, to prepare teachers to succeed in interdisciplinary education, there is a significant need to prepare future administrators and those at the highest policy levels to support and value the work that teachers are doing.

> *"I think probably, if we're going to do something about that [increasing the reach of interdisciplinary education], it's going to take a change from classroom to policy level. Classroom teachers think that there are barriers in their way, which often there aren't, but they think they are. Policymakers are promoting it but not realizing sometimes that if I'm judging you solely on the basis of a test for accountability, then I'm sending mixed messages."*
>
> — Stephen Pruitt

One danger of not focusing on policy changes needed at the district level is that individual schools of excellence, where interdisciplinary education is flourishing, may emerge. In these cases, equity concerns within districts surface as parents with resources seek out the school. Systemic change is needed, with policies and structures applied throughout a district or state, so all students benefit.

Accountability policies. Researchers and practitioners recognized that what gets tested is what gets taught, so either accountability policies must shift so that schools have the space to incorporate interdisciplinary instruction or district and state leadership must find ways to creatively work within the current accountability policies and include interdisciplinary approaches within the accountability framework. Beth Allan noted that limiting accountability to math and reading test scores has meant science is often excluded from elementary instruction. She referenced the National Academies of Science, Engineering, and Medicine *Call to Action* report (focused on science instruction but relevant for interdisciplinary instruction), which recommended inclusion of science in accountability and in expectations of teachers so the subject receives instructional time in the classroom. Implementing new accountability measures is one way to signal where priority is being placed, and interdisciplinary instruction could potentially be included in a similar way. Practitioners further confirmed that adopting new state standards or new accountability tests triggers changes at the classroom level. One district leader in North Carolina noted that new standards can "call for a different way of teaching which is oftentimes what it takes to transform the way that we go, that sets the tone for what should be happening in the classroom, and then testing the impact of that. If the tests change, then we are more likely to change our instruction. So then we see that it's

> *"The biggest part of the stumbling block is the administration support—the local, regional, and state administration support from an educational perspective. Whether that's the school principal or the county or district superintendent. Not so much perhaps adopting but enabling those pioneer teachers to take that bold step and not be constrictive in their policies that hinder those teachers from pioneering a new approach. I still think it's the local and regional education administrators that hold the key to it."*
>
> — Louie Lopez

valued, when we see that we have that flexibility and that freedom to teach a different way than maybe we were taught."

Stephen Pruitt, on the other hand, argued for getting creative within current assessment and accountability structures. States currently vastly underestimate the latitude they have under the Every Student Succeeds Act in terms of accountability requirements. For instance, assessments in CTE could allow students to demonstrate proficiency in math, literacy, and in some cases, science. Work is needed to design assessments with items "meta-tagged" to math and literacy standards as well as CTE standards. This type of effort requires a large pool of items and the political will to undertake it.

District curriculum adoption. Adoption of curriculum at the district or state level can shift the focus of instruction, quickly reach all students, and signal to educators the educational priorities. Mike Gallagher described the Mi-STAR interdisciplinary curriculum used in districts throughout Michigan. Although it has existing unit challenges, districts can adapt them so they are more authentic and locally relevant. He describes the benefits of districtwide curriculum adoption: "Instead of being haphazard or randomly distributed for special teachers, every district that adopts this curriculum is doing this.… My feeling is the biggest lever we have is to systematize things with really strong, well-written curriculum and ample professional learning to help teachers enact it the way it's designed."

Accreditation policies. Accreditation offers another way to ensure that district administrators are informed of pertinent pedagogy and able to support interdisciplinary education. As district leaders noted, without top-down support in a district for interdisciplinary approaches, it is difficult to get teachers to shift their instructional approaches given all their other responsibilities. To reach this level of district support, district and school leaders should have a deep understanding of the pedagogical approach so they can provide structures that will facilitate its successful implementation, including the necessary flexibility in the master schedule, giving teachers ownership of how they design interdisciplinary classes, giving teachers time and other needed resources, and facilitating collaborative structures. Even school board members, who have significant decision-making authority but are often community members and not educators, need to be educated on the value and purpose of interdisciplinary education.

Multipronged approach. Researchers and practitioners recognized that without a multipronged approach that included teacher training, accreditation policies, accountability policies, curriculum development, and capacity development at the district level, shifts in educational priorities and practices that enable interdisciplinary learning would not occur. Charlene Czerniak summarized the challenge: "So they end up having these integrated kind of methods courses and so forth, but unless the accreditation agencies start to focus on this, it's never going to truly change in teacher prep. So, given the nature of our country's educational system, it's almost like that multifront.… How do you tackle teacher accreditation so that that changes the way teachers are prepared … How do you tackle these standardized tests, unless these companies step up and start doing it?… It almost has to be a multipronged focus the way our system's set up,... and a coordinated multipronged system, almost like the accreditation has to work with the publishing companies for the curriculum and the testing companies and all that all at once."

Within a single district, then, a multipronged approach is needed to establish the series of supports, represented by policies and structures that facilitate interdisciplinary instruction, that can connect individual classroom teachers all the way to district superintendents. Jennifer Lutzenberger Philips described the series of supports—from district superintendents to assistant superintendent to district instructional coaches to school leaders to classroom teachers—as the "bucket brigade," arguing the support (bucket) must be passed successfully all the way through the brigade to reach students in classrooms. Changes are needed across multiple levels (teacher, principal, district leader) and across multiple categories (policies, structures, and supports) in the education system.

5.3 Making the Case for Interdisciplinary Education

Researchers and practitioners agreed that an interdisciplinary education approach had the potential to connect students to authentic issues, equip them with skills to solve problems, and increase engagement. In addition, there was wide recognition that the U.S. education system should be preparing students in ways that would allow them to tackle critical questions facing society in the near and distant future. One major challenge with broadening the reach of interdisciplinary education is how to advocate for a shift in instructional approaches, especially one that requires changes to multiple levels of the education system. Respondents approached this issue from multiple angles, including building the evidence base using traditional standardized assessment outcomes; building the evidence base using outcomes more relevant to interdisciplinary learning; demonstrating gaps between visions of education outcomes and the existing curriculum; establishing proof points in schools or districts to make the case for a broader adoption; and making the case to parents and families for a shift in approach.

5.3.1 Building Evidence Base

Test scores as outcomes. Respondents described examples of the effectiveness of interdisciplinary approaches for improving student outcomes on traditional achievement measures and improved test scores that often served as an entry point to implementing interdisciplinary curriculum more widely in schools and districts. For instance, the National Writing Project's Connecticut Writing Project State Network and EL Education's curriculum, as well as smaller scale projects, such as Charlene Czerniak's NURTURES project, have evidence of effectiveness on student standardized test outcomes. Elyse Eidman-Aadahl and Ron Berger both noted that their curriculum was taken up by lower performing districts with potential for improving test scores. Even though low test scores are the entry point, students often demonstrate increased engagement, leading to teachers embracing the curriculum.

> *Schools may initially start to take up this work when they see their scores in writing are not very good. Somebody will say: we need to improve our scores, and you have data, so come work with us. These might be rural schools or under-resourced schools, but they want to improve. And so teachers start working as colleagues in those buildings, starting to have real conversations about stuff with students and doing real intellectual work.… The young people respond insanely well. And when they do, the teacher starts to like it, too, because a happy and productive classroom is a good thing.*
>
> — Elyse Eidman-Aadahl

Although the evidence on interdisciplinary curriculum or approaches improving test outcomes is limited, school leaders emphasized the importance of convincing teachers of the value and impact of interdisciplinary education. This imperative includes providing a strong, long-term evidence base for increased learning outcomes and engagement for all students, including those who are in traditionally underperforming groups, such as English learners or students with learning disabilities. Even teachers called for hard evidence on how interdisciplinary approaches can produce improvements in students' test scores, because their evaluations and, in many cases, pay are tied to student performance on these tests. One teacher noted, "But until there is hard evidence and teachers that they know and trust who will lead them in that direction, you're not going to see a big change because of those narrow, little, multiple choice tests."

Although linking interdisciplinary education to improved test scores can make the case for increasing its implementation in schools, multiple respondents cautioned about limitations of using this type of evidence. For instance, data suggesting that interdisciplinary education improves test scores do not provide any evidence on the mechanisms responsible. More research is thus needed to investigate whether, and more importantly *how*, interdisciplinary instruction is superior to other instructional methods. Many unanswered questions remain about how interdisciplinary approaches lead to better outcomes on tests.

Other student outcomes. Focusing on tests scores as evidence maintains a very narrow view of educational outcomes and prevents policymakers, educators, and parents from seeing potential benefits of interdisciplinary approaches. Julie Thompson Klein noted that "the literature on learning assessment long ago recommended taking a multimethodological approach, including quantitative and qualitative measures, but state boards of higher education, professional societies, and funding agencies keep reinscribing a narrow quantitative approach because that's what they consider evidence." She and others argued that a more diverse set of indicators on appropriate outcomes are needed. Thus, the field must carefully consider the most important educational outcomes for students as well as the key impact of interdisciplinary education.

Mike Gallagher noted that one key outcome might be the change in "students' ability to transfer their knowledge to other domains and apply that knowledge" in a completely different, novel project or novel problem. More research is needed to measure and track whether this is the case in interdisciplinary instruction and the conditions needed for it to occur. Other respondents suggested that student connection or engagement is a key outcome of interdisciplinary approaches. Kelly Day commented, "As a practitioner, my biggest outcomes is when I do a lesson like this is that kids make connections to what we're doing in class to job opportunities later. And I think that that's not an outcome that's often talked about." Similarly, Eliot Levine urged more research is needed around whether interdisciplinary approaches increase engagement: "So does it lead to greater engagement? Does that engagement lead to improved student outcomes? We need more evidence.… However, we have ample evidence that the existing system isn't working well for a huge number of students. So it's essential to continue engaging in innovative approaches such as interdisciplinary learning at the same time that we're building a more rigorous evidence base."

Although rigorous evidence on effectiveness of interdisciplinary education may convince districts to take up interdisciplinary curriculum, parents also need to be convinced that shifting the educational approach in their children's schools will not result in harm to learning. As most parents are not consumers of research, Paul Sutton argued that trying to justify uptake of interdisciplinary education using traditional test scores will be a losing battle, since those tests are not the goal of interdisciplinary education. Instead, a broader argument must be made around the value in interdisciplinary learning experiences for children. He noted, "It's [interdisciplinary learning experiences] got nothing to do with the test scores. It's about the kind of people we want our system to create. But I just don't see a whole lot of arguments being built up around that…. So, it's also incumbent on us as a profession, as researchers, as scholars, as practitioners to make the better argument that will resonate with more people. Again, trying to convince folks that interdisciplinary education will increase test scores completely undercuts the wonderful philosophical argument to be made about interdisciplinary education."

5.3.2 Convincing District Leadership

Gaps between vision and reality. Many respondents acknowledged that district leadership is not poised to support innovative, student-centered learning approaches like interdisciplinary education, in part because of the accountability pressures placed on districts as well as inertia. One way to approach this case-making for administration is through district missions and connecting interdisciplinary education to a district's "portrait of a graduate." David Moss noted that these graduate portraits often include characteristics such as "critical thinkers, global citizens, on and on." One way to make the case for interdisciplinary education would be to ask school board and district leaders how their curriculum purposefully teaches towards their vision for the graduate and to demonstrate the gap. He noted, "At that policy level, I think the very first resources should be towards helping people see the gap between who they claim our graduates should be, and what their curriculum is actually doing."

Proof points. To make policy changes at the district level, multiple respondents described needing "proof points." Jennifer Lutzenberger Philips noted, "Our work right now in New Mexico is an example of this where we're having simultaneous policy conversations while we have conversations with districts. You're not going to get a policy change if you don't have at least a proof point. That just doesn't work." ConnectED builds from its proof points in single districts where it is currently working and succeeding, to inform policy at the state level. Often it starts with a multiyear initiative in a single district, subsequently growing to a multiyear, multidistrict effort that can be leveraged for larger changes.

Similarly, Stephen Pruitt advocated a multistep strategy for advancing interdisciplinary approaches, starting at the state level. He advised that he would first pull together education chiefs and education chairs from legislative bodies in a given region to discuss ways to be more innovative in the approach to assessment accountability, noting what goes on in other countries but also pointing to concrete things that could be considered locally. The second step would be to identify two or three states willing to test the approaches, focusing on how to navigate the system with the federal government and building buy-in among local educators and policymakers. Once demonstrated to be successful in two or three places,

he noted that the hope would be that it spreads to other states. The proof points are crucial to demonstrating the possibility and developing a system or model that others can follow.

Broadening the Reach of Interdisciplinary Education: Summary of Key Findings

- Multiple supports, resources, and structures are needed at all levels of the education system to broaden the reach of interdisciplinary teaching and learning.
- Although several interdisciplinary curricula exist, researchers and practitioners identified an acute need for additional curricula, frameworks or templates, and worked examples of high-quality interdisciplinary instruction to reach teachers "where they are." Preservice and in-service professional development are needed.
- Support must begin at the district level, so that school leadership feels encouraged to provide teachers the resources, time, and support that they need to implement interdisciplinary teaching in their classrooms.

6. Conclusion

With its origins over a century old in the work of John Dewey, interdisciplinary education is not a new instructional approach. Yet individuals working in a variety of roles and organizations across the education field recognize its increasing relevance as an approach that can help students engage authentically in school and prepare them to investigate and solve the most pressing problems facing society once they complete school. This report summarized findings from 28 individuals working in areas related to interdisciplinary education, with the aim of better understanding the current landscape of interdisciplinary education including definitions, examples, reach, roadblocks, and the potential for its expansion in the field of education as well as necessary resources, supports, structures, and policies.

Although those interviewed recognized that challenges, problems, and concerns of today and the future will require an interdisciplinary approach and that students would benefit from interdisciplinary learning, they also had strong cautions against embracing interdisciplinary education for its own sake. Respondents were clear that authentic education, with real-world relevance to students, that has a purpose and elicits quality work from students, is the ultimate goal. Interdisciplinary teaching and learning is a major approach to accomplishing that goal.

Yet, the current reach of interdisciplinary education is limited. Interdisciplinary approaches tend to be implemented in high-income school districts where district leaders are not concerned about raising test scores and state and federal accountability policies because their schools perform well. In contrast, students in low-performing schools and other students who may not demonstrate proficiency on math and literacy assessments have little opportunity to implement or engage in interdisciplinary approaches. Given that one of the purported benefits of interdisciplinary learning is increased student engagement, particularly for those who may not see the relevance of traditional school disciplines, the current

patterns of access to interdisciplinary opportunities are highly inequitable and the reverse of what is needed.

Significant roadblocks to adopting interdisciplinary approaches, though, remain in K–12 education. Both researchers and practitioners identified multiple resources and supports needed by teachers, including curricula or frameworks, worked examples, and significant preservice and in-service professional development opportunities. In addition, increased levels of support, beginning with school leadership and extending up through top levels of district leadership, is required to change the structures and policies that affect classroom teaching. Beyond the district level, state and federal accountability policies and the accompanying standardized tests are major inhibitors of interdisciplinary approaches, according to researchers and practitioners. For the reach of interdisciplinary education to expand significantly beyond “beautiful case studies,” change at multiple systemic levels is needed.

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Appendix A. Literature Review Search Strategy

Table A-1. Literature Review Search Strategy

Search criteria	Research question	First level	Second level	Third level
1	1. How is interdisciplinary education currently defined and by whom? To what extent does interdisciplinary education overlap with or distinguish itself from other educational approaches, including transdisciplinary education, integrated education, and convergence education? 2. In what contexts (i.e., within traditional schools in core academic classes, electives, or career pathways; in nontraditionally structured schools; outside of formal school time), with what student populations, and in what content or disciplines is interdisciplinary education being implemented?	[“interdisciplinary” or “multidisciplinary” or “transdisciplinary” or “integrated” or “integrated STEM” or “integrative” or “convergence”] and [“education” or “learning” or “studies” or “instruction” or “curriculum” or “curricula”]	[“define” or “definition”] or [“model” or “design” or “discourse” or “approach” or “program” or “framework”] or [“implement” or “implementation”] or [“content” or “setting” or “school” or “student” or “background” or “characteristic” or “policy” or “policies”]	
2	1. What is the existing evidence base for interdisciplinary education on student outcomes? To what extent are outcomes related to student characteristics? 2. What gaps currently exist in the research literature on interdisciplinary education?		[[“student”] and [“outcomes” or “academic” or “evaluation” or “achievement” or “testing” or “assessment” or “skills” or “understanding” or “knowledge” or “comprehension” or “engagement” or “motivation” or “perseverance” or “critical thinking” or [“social” and “emotional”]] or [“gaps” or “issues” or “concerns” or “systematic review”]	[“elementary” or “middle school” or “middle grades” or “junior high” or “high school” or [{“second” or “third” or “fourth” or “fifth” or “sixth” or “seventh” or “eighth” or “ninth” or “tenth” or “eleventh” or “twelfth”} and {“grade”}]]

Appendix B. Interviewee List

Researchers, Program Developers, Organizational Leaders

Dr. Elizabeth "Beth" Allan
Retiring President 2021–2022
National Science Teaching Association

Professor of Biology and Coordinator of the Secondary Science Education program
University of Central Oklahoma

Ron Berger
Chief Academic Officer
EL Education

Veronica Boix Mansilla
Principal Investigator
Project Zero, Harvard Graduate School of Education

Dr. Charlene Czerniak
Distinguished University Professor of Science Education
University of Toledo

Kelly Day
Albert Einstein Distinguished Educator Fellow
U.S. Department of Energy

Dr. Nell K. Duke
Professor, School of Education
University of Michigan

Leslie Eaves
Project-Based Learning Program Director
Southern Regional Education Board

Elyse Eidman-Aadahl
Executive Director
National Writing Project

Nat Erbes
Curriculum Manager, Middle Years Programme
International Baccalaureate Organization

Edward Geary
Principal Investigator, National Science Foundation award: "The Next Generation of STEM Teacher Preparation in Washington State"
Western Washington University

Robin Julian
Curriculum Manager, Extended Essay & Social and Cultural Anthropology
International Baccalaureate Organization

Dr. Julie Thompson Klein
Professor of Humanities Emerita, English Department
Wayne State University

International Research Affiliate, Transdisciplinarity Lab in Department of Environmental Systems Science
ETH Zurich

Nikhil Laud
Co-coordinator of Ethnic Studies Program
San Francisco Unified School District

Dr. Eliot Levine
Research Director
Aurora Institute

Louie Lopez
Director, U.S. Department of Defense STEM
U.S. Department of Defense

Dr. David Moss
Associate Professor
University of Connecticut, Neag School of Education

Jennifer Lutzenberger Phillips
Director of Learning, Teaching, and Pathway Development
ConnectED: The National Center for College and Career

Stephen Pruitt
President
Southern Regional Education Board

Dr. Paul Sutton
Assistant Professor of Education
Pacific Lutheran University

Practitioners

Teachers

Theresa Goltermann
Middle school career and technical education teacher

April Swarey
High school English teacher

Shelby Watts
Fourth-grade teacher

School Leaders

Toni Kaui
Principal

Christina (Chrissy) Romero
Digital Learning Coach

Tameka Woodruff
STEM Instructional Coach

District Leaders

Leanne Daughtry
Director of K–12 Math and Science Curriculum

Mike Gallagher
Oakland MiSTEM Network Director
Oakland Schools, Michigan

Linda Tugurian
Coordinator for Secondary Programs and STEM Integration

Appendix C. Interview Protocols

Researcher Interview Protocol

Background

1. Can you share a bit about your work as it relates to interdisciplinary education?

Questions

Definition of Interdisciplinary Education and Related Terms

2. How would you define interdisciplinary education?
3. How do you see interdisciplinary education as distinct from other related terms such as transdisciplinary education, multidisciplinary education, thematic integration, integrated education?
4. What are the similarities between interdisciplinary education and other related terms?
5. Do you have a preference for any terms? Do you think the terms used are important? Why or why not?
6. Are there other educational approaches that are similar to interdisciplinary education? How are they similar or different?
7. How does interdisciplinary education support, if at all, educational equity and/or equity-centered teaching and learning?
    a. What are ways that equity-centered educational approaches overlap or conflict with interdisciplinary approaches?

Identifying Areas of Success and Areas for Growth

8. What aspects of or approaches to interdisciplinary education have you observed to be successful in terms of improving student outcomes?
9. What do you think the field of interdisciplinary education needs in order to advance (in terms of approaches and implementation)?
    a. What areas for growth do you see in interdisciplinary education approaches and implementation based on your perspective and work?
10. What groups of students, if any, have you observed facing more barriers to access interdisciplinary education than others?
    a. What factors have contributed to these groups facing greater barriers to interdisciplinary education?
    b. Have you observed certain groups of students receiving greater access to interdisciplinary education (fewer barriers)? What are these groups and why are they more heavily represented?

Supports and Policies Needed to Implement Interdisciplinary Education

11. What supports or resources are <u>currently available for practitioners</u> to be able to successfully adopt and implement interdisciplinary education?
12. What supports or resources are <u>still needed for practitioners</u> to be able to successfully adopt and implement interdisciplinary education?
13. What policies or structures are <u>currently available at the state, district, or school level</u> to be able to successfully adopt and implement interdisciplinary education?
14. What policies or structures are <u>still needed at the state, district, or school level</u> to implement interdisciplinary education more widely?
15. What major roadblocks, if any, do you see for districts, schools, and teachers adopting and implementing interdisciplinary education?
16. **[If relevant for respondent]:** How would you describe the role of assessment in interdisciplinary education? How do you see the current state of assessment in this field?

Wrap-Up

17. Is there anything else you think would be important for us to know about interdisciplinary education that we haven't asked about?
18. Do you have any suggestions for individuals that we should reach out to for an interview on interdisciplinary education? If so, what is their role in the field and how would they add to or enrich this conversation?

Practitioner Interview Protocol

Questions

Prior Experience with Interdisciplinary Education

1. How would you define interdisciplinary education? What does the term mean to you?
2. From your perspective, what approaches or methods of instruction are consistent with interdisciplinary education? How so?
3. Have you had any previous training or professional development related to interdisciplinary education?
4. Have you had any experiences engaging students in interdisciplinary education in your classroom? Has your school/district had any experiences engaging students in interdisciplinary education in your schools? Describe any benefits to students and any challenges faced.
    a. If not, why not? Is interdisciplinary education something you'd like to implement in your [class/school/district]?
5. How do you think interdisciplinary education relates to equity-centered teaching, if at all? What are areas of alignment or difference?

Supports to Develop Capacity and Implement Interdisciplinary Education

6. How supported do you feel to *develop your capacity* to implement interdisciplinary education? That is, how supported do you feel to receive professional development around interdisciplinary education? Is interdisciplinary education an identified priority for your school/district?
7. How supported do you feel to *implement* interdisciplinary education in your district/school/classroom?
8. What additional supports do you need or would be helpful for implementing interdisciplinary education in your district/school/classroom, if any?
9. What types of empirical evidence/research would be helpful to support a shift in your school/district to using an interdisciplinary approach?

Challenges to Adopting and Implementing Interdisciplinary Education

10. What major roadblocks, if any, do you see for [districts, schools, and teachers] to adopt and implement interdisciplinary education?
11. How do *policies* at school, district, state, and federal levels enable or hinder interdisciplinary approaches?

Opportunities to Access and Benefits For Students

12. What opportunities currently exist in your school (or district) for students to access/engage in interdisciplinary education?
13. What groups of students, if any, have you observed facing more barriers to access interdisciplinary education than others? *What factors have contributed to these groups facing greater barriers to interdisciplinary education?*
14. If you have had experience engaging students in interdisciplinary education in your district/school/classroom, what benefits have you observed for students?

Wrap-Up

15. Is there anything else you'd like to share that I haven't asked about?