Integrating and Aligning Semiconductor Across K-12 STEM Education

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Integrating and Aligning Semiconductors Across K-12 STEM Education

(Work-in-Progress)

Introduction

Semiconductors, both as a material and an industry, are pivotal to modern electronics, enabling the creation of microchips or integrated circuits that power today's technology. Following the passage of the CHIPS (Creating Helpful Incentives to Produce Semiconductors) and Science Act of 2022, investments in United States semiconductor production have surged, highlighting the need for workforce development to support this expanding industry. In response, efforts have emerged to introduce semiconductor content into K-12 education, aiming to inspire and prepare students for engineering and technology careers in this critical field. This work-in-progress paper explores how one K-12 workforce development initiative seeks to vertically align semiconductor education across entire school districts, ensuring that learning and experiences progressively build in complexity from kindergarten through high school. Vertical alignment (VA) is crucial for advancing students' understanding and preparing them for potential career pathways in semiconductors. VA also enables schools to develop plans for embedding such workforce initiatives into school policy, helping to sustain the integration efforts over time. This paper presents preliminary results from an analysis of VA plans developed by seven school districts within a prominent semiconductor industry network. Through document analysis, we identify and critique how these schools plan to integrate semiconductor content across grade levels and subjects. The preliminary findings aim to provide valuable lessons for other workforce-driven STEM initiatives and offer potential models for integrating semiconductor education in K-12 classrooms. The research question guiding this investigation is: How does the VA of semiconductor contexts/content emerge in K-12 classrooms within and across school districts, grades, and disciplines?

Background & Context

The global semiconductor crisis, triggered by the COVID-19 pandemic, emphasized the critical role of microchips in modern industries and exposed vulnerabilities in global supply chains. The shortage disrupted industries ranging from automotive to consumer electronics, highlighting the United States' reliance on foreign semiconductor manufacturing. This crisis was not only a logistical bottleneck but also a risk to national security and economic stability. In response, the United States government enacted the CHIPS and Science Act, a landmark investment aimed at bolstering domestic semiconductor manufacturing and reducing dependence on foreign supply chains (The White House, 2024). The act allocated billions of dollars to developing facilities, advancing research, and fostering workforce development. As mentioned earlier, the growing emphasis on semiconductors has created an urgent need for a highly skilled engineering and technology workforce to sustain the industry's long-term competitiveness (Deloitte & Global Semiconductor Alliance, 2023). Addressing this demand requires aligning K-12 curricula with workforce needs.

The workforce development initiative at the center of this study seeks to integrate semiconductors into K-12 education through five core elements: curriculum development, professional development, VA, out-of-school experiences, and a continuous improvement cycle. This collaborative effort—led by teachers, university faculty, industry partners, and graduate researchers—has developed, tested, and refined curriculum units designed to progressively introduce students to semiconductor concepts and skills. Professional development workshops have equipped teachers with strategies to deliver these units effectively. Out-of-school experiences, such as summer camps, have provided high school students with advanced engineering learning opportunities related to semiconductors and microelectronics. Central to this initiative is VA, which ensures that foundational knowledge in early grades is systematically built upon in later grades, preparing students for advanced skills and careers. VA refers to the intentional sequencing of curriculum content and experiences across grade levels. When done well, VA can create a coherent learning progression and students can build on prior knowledge and skills overtime (El Zomor et al., 2018; Fulmer et al., 2018; The Center for Comprehensive School Reform & Improvement, 2009; Watermeyer, 2011).

This process requires pinpointing what knowledge and skills are grade-level appropriate within the core ideas of a given content area (Bergman et al., 1998). VA does not only refer to curriculum alone. To plan and implement vertically aligned content and experiences, collaboration is needed between teachers across grade levels with strategic facilitation from district-level stakeholders/administrators (Bergman et al., 1998; Robinson, 2000). Accordingly, VA is also seen as a strategy for sustaining a school's integration of semiconductors overtime. The lack of VA practices, however, can result in fragmented learning, redundancies, and missed opportunities to prepare students for emerging career pathways (Suffren & Mezera, 2018). But, by aligning semiconductor content vertically, there is an opportunity to create a coherent learning progression that integrates foundational concepts in elementary school, interdisciplinary applications in middle school, and advanced problem-solving and career exploration in high school.

Despite its apparent importance, the process of VA has not been examined in regard to integrating novel STEM workforce contexts. This gap can leave schools without clear frameworks for aligning curricula to ensure consistent content progression and career readiness. For example, there can be significant challenges regarding the implementation of VA practices, such as inconsistent curriculum delivery, varying levels of teacher preparedness, overcrowded schedules that limit collaboration across grades, and school district/community buy-in. Nevertheless, by examining the VA process of this K-12 semiconductor initiative, we can begin to explore how the VA of semiconductor content can be implemented across school districts, highlighting the successes, challenges, and actionable insights that can guide future workforce-driven STEM education initiatives. We then hope that this preliminary work can begin to contribute to the growing conversations on aligning education with workforce demands, providing future models for other STEM initiatives seeking to prepare students for high-demand engineering and technical careers.

Methods

To investigate the integration and alignment of semiconductor education across K-12, VA plans were collected from seven school districts participating in a semiconductor education initiative. These plans were developed collaboratively by school district teams that included educators and administrators spanning grade levels, as well as members from a regional workforce development organization. The vertical alignment process is detailed in Appendix A. Each district's VA plan addressed the following key questions developed by the workforce development organization:

1. What robotics, coding/programming, electronics, and engineering tools will students use, and what skills will they learn at this grade level?
2. How will you expose students to careers in the semiconductor industry?
3. What employability skills are important at this grade level, and how will they be developed?
4. What additional resources or connections will you incorporate?

The VA plans outlined how semiconductor-related activities and career connections would be implemented for an entire school year, covering grades K-12. Two example summaries of district VA plans are provided in Appendix B. To analyze these plans, the research team utilized a document analysis approach. Each team member independently reviewed the plans to identify themes and patterns. Regular meetings were conducted to compare findings, address discrepancies, and refine the coding framework. Additionally, the team explored precedents of vertically integrated topics across K-12 education to contextualize the approach within existing educational models. The iterative analysis allowed the team to synthesize findings across districts/grade levels.

Preliminary Findings

The analysis of the VA plans from each school district provides a perspective of how educators and administrators planned to integrate semiconductor content/experiences across schools, grades, and subjects. The preliminary findings are presented in the following sections, organized by grade level.

Grades K-2: *Introducing Semiconductor Concepts Through Play and Visuals*. At this level, VA plans emphasized hands-on and play-based learning. For example, planned activities include the use of visual and graphic aids, such as picture cards and design prompts, to simplify complex concepts and engage young learners—mostly in basic coding and technical problem-solving. Physical coding tools and robotics platforms such as Code-a-Pillars, Dash and Dot Bots, or LEGO Robotics were commonly identified as a way to introduce foundational ideas like computational thinking. While these tools offer an introduction to foundational concepts like basic electronics, coding, and programming through playful engagement, one thing noted in the analysis is that they may use semiconductor-related products but may not always directly introduce semiconductor content.

Introduction to Field Trips and Engagement with Community Partners. Field trips and engagement with community partners also were common across the school plans at this grade level, highlighting a goal of exposing students to both STEM concepts in general and the semiconductor industry specifically. For instance, some districts have planned visits to local semiconductor companies, while others invited local companies to elementary school family nights or science fairs, where students and parents learned about products, available jobs, and the basic skills required in local industries. Some schools even indicated trips to a semiconductor defense site for their younger students, offering them early exposure to defense-related microelectronics. Another school district focused on family engagement, where students learned about semiconductors through family careers and show-and-tell activities that connected everyday electronics to semiconductor concepts. These experiences were intended to spark early interest in STEM careers and provide context for learning about the semiconductor industry.

Grades 3-5: *Developing More Foundational Skills Through Hands-On Activities*. In grades 3-5, plans mostly focused on building foundational technical skills related to electronics and programming for students. Activities included intermediate block coding, circuit-building with “snap together electronic components,” engineering design tasks, and STEM challenges using robotics such as VEX Go. The goal of these activities was to engage students in learning concepts related to the engineering design process, programming physical devices, and basic electronics without breadboarding or soldering.

Use of Preexisting Curricula. Many of the school initial plans relied heavily on preexisting school curriculum, mostly from the engineering and technology subject, as a means for vertically aligning the integration of semiconductors across the grades. The most common pre-existing curriculum used across the schools was from the Project Lead The Way (PLTW) vendor. At this grade level, the PLTW curriculum is called “Launch” and is designed to engage students in hands-on projects that blends concepts from computer science, engineering, and biomedical science. While the activities within this curriculum can certainly help develop foundational skills/knowledge related to the field of semiconductors and makes sense for these VA plans as it provides a place for integration, a concern can be that this curriculum is not designed with explicit connections to semiconductors. As a result, without buy-in from the teachers to make clear connections with the industry, students could then miss an introduction to the field and the connections across the grades. This idea can solidify why the VA process is a critical method for integrating the workforce context as it plans for providing awareness to teachers for making the explicit industry connections.

Community Industry Connections. Industry connections were a focus at this grade level, with schools planning for field trips to research institutions, Department of Defense entities, and inviting guest speakers to discuss career pathways and experiences with the semiconductor industry.

Grades 6-8: *Expanding Skills Through Engineering and/or Semiconductor-focused Curriculum*. At the middle school level, VA plans increasingly focused on leveraging pre-existing engineering curriculum and/or semiconductor-specific curricular units. The engineering curriculum targeted was again offered by the PLTW vendor. At this level the PLTW curriculum is titled Gateway. The Gateway program includes a variety of units that explore topics such as design and modeling, green architecture, automation and robotics, energy and the environment, and the magic of electrons while connecting students with related career fields. The curriculum incorporates hands-on projects that apply the Engineering Design Process, teaching students to design, test, and improve solutions to real-world problems. While the different Gateway units can provide valuable STEM experiences for students, obviously certain units such as the Magic of Electrons are better aligned with the semiconductor field.

The semiconductor-specific curricular units are the ones created through the semiconductor education initiative at the center of this preliminary study. These units are designed to integrate semiconductor content/contexts specifically within the different subject areas as part of that subject’s curriculum. These units included one for mathematics, one for engineering/tech, one for science, one for social studies, and one for English language arts—enabling semiconductor education to be implemented in different subject areas and allowing for broader student engagement as well as multiple touchpoints. For example, the mathematics unit teaches students about geometry by engaging them in a task from a fictitious semiconductor company that involves calculating silicon wafer waste, silicon wafer production, and silicon boule waste, to ultimately design an efficient process to layout a silicon wafer for microchip manufacturing. With these curricula, the VA plans also introduced goals for the use of more advanced tools/technology and the integration of targeted concepts specific to the semiconductor industry to expand upon foundational knowledge acquired in earlier grades. For example, the plans highlight students use of programming tools like Scratch, Blockly, and Python, robotics activities using VEX Robotics, and tools to design/fabricate models to engineering activities.

Continued Career Integration Activities. In grades 6-8, planned career exploration activities appeared more focused, with students participating in site visits to facilities and engaging with engineers to learn about industry roles. These experiences aimed to connect classroom learning with real-world applications, hopefully preparing students for more specialized learning in high school. However, potential redundancies in these experiences were observed, which could result in students across multiple grades within districts visiting the same sites without clear progression in the experiences. This potential issue is another reason why a VA approach is made. When the school-district VA teams meet, it is these types of redundancy concerns that they seek to identify and address.

Grades 9-12: *More Subject Specific Semiconductor Integrations*. At the High school level, the VA plans included the use of more curricular units designed to provide a deeper integration of semiconductor concepts within specific school subjects. These units were again created by the semiconductor education initiative at the core of this study. The targeted units were developed for algebra, geometry, pre-calculus, engineering/technology, business, social studies, computer science, English language arts, biology, and physics. For example, the business unit engages students in investigating the global supply chain as well as the business needs for microchips and then developing an argument for government investment into onshoring the production of microchips. Also at this level, VA plans emphasize student work with more complex circuit designs, the use of more advanced programming languages such as Python and JavaScript to support applications of semiconductor products in automation/robotics/sensors, and use of more tools such as 3D printers to design prototypes to the engineering activities that are related to the semiconductor industry.

Comprehensive Career Awareness & Opportunities. Career awareness activities became more comprehensive, with students visiting companies, participating in internships, completing state-level workforce education initiatives, and learning directly from industry professionals. This phase emphasized real-world applications and workforce readiness skills, helping students connect academic learning to potential careers. Also, the VA plans included connections with curriculum for specific career and technical education pathways such as the PLTW Engineering Pathway. While these programs are great for those who have already decided on an engineering-related career pathway, they do not typically engage the broader student population within school districts—providing a rationale for the continued use of the curriculum designed for use across the broader subject areas.

Discussion

As demonstrated by the data, the VA enabled schools to develop district-wide integration plans, engage with their school communities, and leverage available resources to bring the workforce context of semiconductors to students across all grade levels. Without this process, it is likely that schools would have only implemented isolated "one-off" lessons with a few selected teachers. Instead, the VA process led to the development of comprehensive plans that support sustained integration of this workforce context across grades. Therefore, it is recommended that school administrators and curriculum leaders build from the VA process described in this paper (see Appendix A) when seeking to integrate new workforce initiatives in their districts.

While the VA process appears to be a powerful approach for connecting educators and students with workforce-related content and experiences, the data highlighted several considerations for those undertaking similar initiatives, whether focused on semiconductors or other emerging industries. The following six themes emerged from the data. Notably, these considerations were surfaced and addressed because of the VA process itself—demonstrating its role in identifying and managing the complexity of workforce-driven initiatives. Nonetheless, these themes and the lessons learned may guide others working to vertically align workforce development efforts.

Leveraging Pre-Existing Engineering Curricula. Using existing engineering curricula was a common initial strategy for integrating semiconductor concepts. While engineering courses are a logical entry point, two important caveats emerged. First, engineering curricula are not automatically equivalent to semiconductor education. Although they cover foundational concepts like circuits, design, and problem-solving, they can lack attention to semiconductor-specific content such as doping, photolithography, or chip fabrication. A simple solution is to ensure mindful, explicit connections to the semiconductor industry are incorporated—though this may require teacher support. Second, these engineering courses are often reserved for specific career and technical education tracks, meaning many students may miss out unless content is also embedded in general education.

Using Robotics and Coding Activities. Several of the VA plans emphasized robotics and coding as mechanisms for introducing semiconductor-related skills. While these can be valuable for general STEM engagement, it is important to assess whether they adequately connect to semiconductor design, manufacturing, or applications. For example, robotics can teach automation and programming but may not address what semiconductors are or how they function in electronics. Supplementing these activities with contextualized lessons can strengthen alignment.

Finding Industry Connections. The relative newness of the semiconductor industry in many regions can pose challenges for curriculum development and real-world experiences. VA teams initially reported limited knowledge of the industry and few local professionals available to support instruction. This made career pathway development more difficult. However, establishing a district-wide VA process allowed schools to gradually build those connections over time. Recognizing that industry partnerships evolve slowly is key—another reason why beginning with a structured VA process can be valuable when launching any workforce-driven STEM initiative.

Scaffolding Career Awareness Activities. Some districts noted redundancies in their career awareness experiences—such as repeated field trips to the same sites across grade levels. If left unaddressed, this could reduce engagement and hinder the development of deeper career understandings. In response, VA teams worked to structure career exploration so that each grade level introduced new roles, concepts, or insights. This approach ensures that students receive a coherent, scaffolded exposure to industry and can progressively build their understanding over time.

Aligning STEM Activities and Careers Authentically. Another critical consideration is how well classroom activities align with actual careers in the targeted workforce context. While general STEM activities are valuable, they do not always reflect the diversity of technical, engineering, or non-technical roles in the field. Activities like programming or simple circuit design, while foundational, may not expose students to topics like cleanroom protocols or the role of technicians. Ensuring that classroom experiences authentically reflect current and projected workforce needs is essential for meaningful career guidance and preparation.

Being Mindful of the Right Amount of Integration. VA teams developed a mindful approach to semiconductor integration so that they did not run the risk of overwhelming students with too many connections, potentially driving students away from the industry. So, there appears a need for considering the “right amount” of career connections and concepts for students so that they do not feel bombarded with the workforce context being integrated. Also, as highlighted by the VA teams in their planning, it is important to think through how to introduce concepts at the right age, as younger students may feel disengaged or intimidated if the content feels abstract or overly technical.

Conclusion

This preliminary study analyzed VA plans from seven school districts to explore how semiconductor content is integrated within, and connected across, grades K through 12. Findings show that a district-wide VA process can result in a planned, structured progression of learning—from exploratory activities in early grades to specialized, career-focused content in high school. These efforts reveal VA's potential to transform isolated activities into coherent and sustainable educational pathways. However, several key considerations emerged such as how to appropriately leverage existing engineering curricula and robotics activities, how to scaffold career awareness meaningfully, how to build connections with an emerging industry, and how to calibrate the right amount of integration for students across grade levels. To address these key questions, recommendations for schools include (1) establishing a cross-grade VA team that includes teachers and administrators, (2) recognizing that workforce and industry connections take time to develop, (3) structuring career exploration experiences to build progressively across grades, and (4) integrating industry-relevant content in both general and career-focused classrooms. These preliminary insights highlight VA as a valuable strategy for connecting education with workforce needs, in comprehensive and sustainable way. When implemented thoughtfully, VA holds the potential for aiding students in building foundational knowledge, exploring career possibilities, and developing the skills needed for, and interest in, emerging STEM fields like semiconductors.

Acknowledgement

We acknowledge support from the U.S. Department of Defense [Contract No. W52P1J-22-9-3009], Indiana Economic Development Corporation [Contract No. A281-3-IPF-1028 424208], and U.S. Department of Defense through Applied Research Institute [Contract No. SA-22036.001].

Appendix A

Figure 1. Vertical Alignment Process

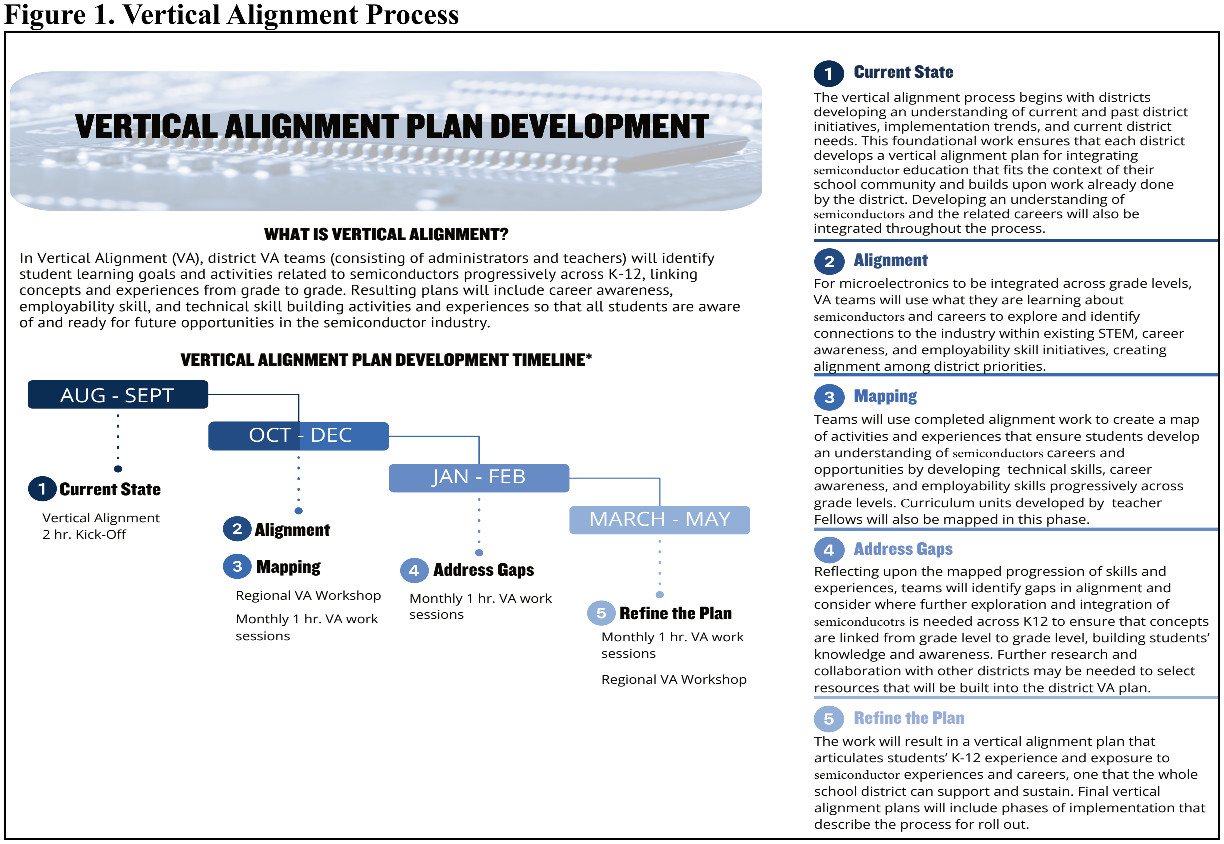

Figure 2. Example School District VA Plan Summaries

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