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Building Collaboration and Knowledge in Semiconductor Research: A Case Study on CHIPS & Science Act Workshops

PERSPECTIVE

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ABSTRACT

This study explores the impact of Creating Helpful Incentives to Produce Semiconductors (CHIPS) & Science Act researcher development workshops conducted at a single research-intensive university in the United States, with the overall goal to align with national priorities in semiconductor research, workforce development, and education. This $50 billion legislation, passed in August 2022, envisions a shared ecosystem among states, industry, and higher education designed to propel the nation's contribution to the semiconductor industry. In response to this national initiative, one university launched a series of workshops designed to equip researchers with the tools and networks necessary to drive impactful research. Using a mixed approach of descriptive findings and qualitative research, this research examines how three workshops facilitated in 2023 fostered collaboration, knowledge sharing, and capacity building among faculty and researchers. Each workshop progressively increased in size and scope, beginning within the institution, growing to include the university's system partners, and expanding across the state. The findings, including both a descriptive review of each workshop and qualitative findings, align with the learning theory emphasis, anchoring a design-based research methodology. The descriptive findings review attendee participation, along with workshop materials and resources. The qualitative results report on attendee engagement, including their perceived learning challenges with each workshop. The findings also highlight the workshops' ability to create research teams capable of increasing preparedness for semiconductor-related initiatives, while revealing workshop challenges such as time management and hybrid engagement. Overall, this research provides valuable lessons learned for designing effective researcher development and team formation activities to effectively respond to emerging national needs.

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INTRODUCTION

In an era of rapid technological advancement and global competition, the semiconductor industry is pivotal for driving innovation and economic growth. Recognizing this, the United States government enacted a landmark piece of legislation, the Creating Helpful Incentives to Produce Semiconductors (CHIPS) & Science Act, in August 2022, to bolster domestic semiconductor research, development, and manufacturing, and ensure the nation's technological and economic security (White House 2022; U.S. National Science Foundation 2024; Peters 2022). The CHIPS & Science Act represents a significant investment, allocating over $50 billion for semiconductor research and manufacturing incentives (White House 2022). While nearly half the global market of semiconductor sales is purchased by the United States, the country's 'manufacturing capacity has eroded from 37% in 1990 to 12% today, mostly because other countries' governments have invested ambitiously in chip manufacturing incentives and the United States government has not' (Peters 2022, p.1; Su 2022). Considering how US investment has declined and other countries are growing their efforts, technological urgency is created (U.S. National Science Foundation 2024; Patel 2023; Peters 2022; Gunarathne & Chaitanyam 2024).

As a result of this legislation, higher education institutions across the country are expected to take a crucial role in realizing the CHIPS Act's objectives (U.S. National Science Foundation 2024; Patel 2023; Peters 2022; Gunarathne & Chaitanyam 2024). Researchers forecast a STEM talent shortage, with some anticipating this reaching 1.4 million jobs in 2030 (Gunarathne & Chaitanyam 2024; Patel 2023). Although this prognostication is dire for the industry, the 'need for more students in STEM careers' offers career opportunities from technical school to graduate school (Patel 2023, p. 35). Higher education has therefore once again increased the attention paid to STEM curriculum experiences like problem-solving, problem-based learning, and interdisciplinary collaborations (Patel 2023; Clark et al. 2024). In addition to curriculum improvements, increased internships and research experiences offer opportunities for students to connect with industry, and it is not always higher education leading the charge, as industry leaders like Samsung are able to fund '100% tuition and books' (Patel 2023, p. 35). In other examples, academic scientists and researchers are dedicated to material discoveries or manufacturing advancements that make semiconductor parts and processes more efficient, and less expensive (U.S. National Science Foundation 2024).

BACKGROUND

Considering the CHIPS Act as a complex change initiative, the climate for change has been created for both the country and for higher education ecosystems (Kotter 1995; Rude 2023). The sense of urgency is multifaceted, framed by the passing of the legislation, and heightened by the anticipated job shortage (White House 2022; Patel 2023; Gunarathne & Chaitanya 2024; Peters 2022). At a high level, the initiative's guiding coalition involves diverse and emergent stakeholders in government, industry, and higher education (Gunarathne & Chaitanya 2024). For higher education contexts, guiding stakeholders could be those people and disciplines associated with semiconductor research, the curriculum, and workforce development (Patel 2023; Peters 2022; U.S. National Science Foundation 2024). The final step of Kotter's (1995) climate for change phase involves creating a vision. Within higher education, this is how administrators, faculty, students, and educational developers address the pivotal aspirations and demand to fulfill the CHIPS Act's vision.

While Kotter (1995) could be used to frame the national and institutional responses to the CHIPS Act, it is also reasonable to frame higher education contexts with learning theories. Thus, this literature review examines four learning theories that offer valuable foundations for contributing to collaborative learning and initiatives in higher education.

Situated Learning Theory, developed by Lave and Wenger (1991), posits that learning is inseparable from the context in which it occurs. Lave and Wenger (1991) argue that learning is fundamentally a social process where knowledge is co-constructed by participants as they engage in shared practices. Wenger (1998) further developed the concept of communities of practice, which are described as groups of people who share a concern or passion for something they do and learn how to do it better through regular interaction. Tang and Pei (2023) emphasized the theory's aim 'to help learners find solutions to problems through observation, participation, and discovery' (p. 3). Examples of Situated Learning Theory in higher education are often associated with disciplinary fields like learning sciences and educational development, both of which are adjacent to and influence engineering education (Pierrakos 2025; Rude 2023). A recent engineering case study example focuses on experiential learning curriculum redesign (Pierrakos 2025).

Cognitive Constructivism focuses on how individuals construct knowledge through their experiences and reflections (Piaget 1952). Piaget's theory emphasizes the importance of schema building, where learners actively construct mental frameworks to understand and organize knowledge (Piaget 1952). In a systematic review of articles relating to STEM pedagogical experiences between 2000 and 2020, researchers recently discovered that Cognitive Constructivism is largely experienced in North America, while European studies are based in cognitivism (Arevalo-Viveros et al. 2024). Ngo (2024) carried out a constructivist learning environment survey as part of an engineering and technology study. Despite students perceiving only partial implementation in their classes, Cognitive Constructivism continues to 'emphasize the enhancement of student engagement, promotion of critical thinking, and redistribution of power within the classroom setting' (Ngo 2024, p. 20).

Social Constructivism emphasizes the collaborative nature of learning and the importance of cultural and social context in cognition (Vygotsky 1978). In other words, the focus is on the human and their social interactions. Vygotsky (1978) argued that higher mental functions are developed through social interaction outside of the research lab. Social Constructivism offers a theoretical underpinning for research in game-based learning (Cooper et al. 2025) and engineering curriculum design (Umar et al. 2023; Li et al. 2023). In the context of educational development, this theory supports the use of collaborative activities that promote collective knowledge construction (Balfe & Bhroin 2019; Cooper et al. 2025; Resnick & Rosenbaum 2013).

Transformative Learning Theory, developed by Mezirow (1991), focuses on how learners critically reflect on their experiences, leading to a transformation in perspective. Transformative learning involves not just acquiring new knowledge but fundamentally shifting one's perspective or frame of reference, which occurs most often through critical reflection (Mezirow 1991). This theory has been widely adopted by educational developers in scholarship of teaching and learning, faculty development, and interdisciplinary education (Ultsch et al. 2022; Patterson et al. 2019). Similarly to the aforementioned theories, Transformative Learning Theory also offers a foundation for curriculum design, including STEM and non-STEM disciplines (Joslyn & Hynes 2022; Patterson et al. 2019).

A common approach to responding to large change initiatives in academic settings is organizing workshops. However, there is limited research on the theoretical underpinnings and effectiveness of workshop development approaches in the context of rapidly emerging national research priorities. This case study seeks to address this gap by examining participant experiences in three CHIPS & Science Act workshops at a single institution. Therefore, the primary research question guiding this case study is as follows: how effective were the CHIPS & Science Act workshops in fostering collaboration, knowledge sharing, and capacity building among faculty and researchers at the case institution?

METHODS AND PROCEDURES

To answer this overarching study question, educational development researchers employed a qualitative approach in a single case study research design. Descriptive analysis of workshop attendance and format help situate the qualitative analysis of workshop outcomes as perceived by participants. A case study methodology is particularly appropriate for examining complex educational interventions in their contexts, where multiple factors interact and influence each other (Yin 2018).

A large research-intensive university in the southwestern United States established a CHIPS & Science Act Task Force in January 2023. The institution generates over $1 billion annually in research revenue and maintains a grant portfolio worthy of consideration as a regional and national leader in the semiconductor field. This task force, comprising eight experts from various academic and technological domains, was charged with developing strategies to position the university at the forefront of semiconductor research and education. In short, the task force was responsible for creating the climate for change (Kotter 1995).

One of the key initiatives undertaken by the task force was the organization of a series of workshops designed to foster collaboration, share knowledge, and build capacity among faculty and researchers. Three workshops, held between June and October 2023, aimed to create a community of practice for semiconductor research, while also developing interdisciplinary connections to address the challenges outlined in the CHIPS & Science Act. Each workshop expanded in scope and size, and was implemented in a unique delivery format. All workshops provided technical presentations, small group activities, and networking opportunities. Materials included key topics related to the CHIPS & Science Act and semiconductor research, handouts and digital resources providing additional information and guidelines, and co-created workshop artifacts. Notably, the specific technology content evolved across the three workshops, reflecting the expanding scope of the initiative and incorporating feedback from previous sessions based on data analysis.

This case study employed a design-based research (DBR) approach to evaluate the effectiveness of the three workshops designed to address CHIPS & Science Act initiatives (Donaldson et al. 2021; Barab & Squire 2004). DBR is characterized by a number of key elements which identify the value of implementing it for this study. For example, learning theories form a foundation to DBR (Donaldson et al. 2021; Barab & Squire 2004), and, in the case of this research, four principal theories frame the workshop design: Situated Learning Theory, Cognitive Constructivist Theory, Social Constructivist Theory, and Transformative Learning Theory. Another DBR characteristic is the three-iteration process whereby data are collected and analyzed, and findings then influence the iterative learning experience design (Donaldson et al. 2021; Barab & Squire 2004). Here, the workshop design was influenced by the emergent data collected.

Study participants were faculty members and researchers from the university. Because participants from other institutions were excluded from the study, they were not recruited. A post-workshop survey was administered electronically after the workshop. The four open-ended questions invited study participants to describe their overall workshop experience, their experience in small group work, any struggles they encountered during the workshop, and aspects of the workshop they found particularly effective. Participation in any survey was voluntary, and all responses were anonymized to ensure confidentiality. To provide additional context for analysis, researchers also collected workshop agendas and materials from each session.

To achieve three-phase DBR iterative implementation, the analysis involved a qualitative coding approach. Qualitative research design is a methodological process able to investigate and elicit contextual analysis and insights (Creswell & Poth 2018). Three researchers independently identified key themes and patterns in the survey responses, with discrepancies resolved through discussion among the researchers. Descriptive data on each workshop augment the open-ended responses. This case study design and qualitative analysis provide a comprehensive view of participant experiences and the workshops' evolution.

RESULTS

Descriptive results across the three workshops are presented in Table 1 and depict the increasing scope and engagement of the CHIPS & Science Act researcher development initiative.

Workshop One was offered as a single-day, online experience in June 2023. As this was the initial kickoff event of the CHIPS & Science Act Task Force, invitees were limited to institutional stakeholders representing faculty, researchers, and staff. Prior to the workshop, attendees (*n* = 81) were invited to state the CHIPS & Science Act domain in which they desired to engage during the session from 10 topics: Harsh Environments, Advanced Packaging, Process and Production R&D, Microelectromechanical Systems, Memory, Photonics, Power, Bioelectronics, Societal Impacts and Sustainability, and Workforce Development. Task force members facilitated engagement through structured prompts to elicit stakeholder input and perspectives.

Workshop Two, held in August, was a single-day, in-person experience, and workshop attendance (*n* = 142) expanded by including stakeholders from seven institutions and agencies associated with the university system. Workshop Two activities included poster sessions, breakout discussions, and an industry perspectives panel. This workshop was the inaugural event for the Semiconductor Institute, which had recently been established in the university system.

Workshop Three, or the Semiconductor Summit, was designed for engagement within and across the state, and occurred in October 2023. Advertised as the 'state's premier gathering of top researchers and leaders in the semiconductor industry,' (Texas A&M Semiconductor Institute 2023) the two-day hybrid (online and in-person delivery) workshop engaged nearly 250 attendees. This workshop featured working group sessions with experts, as well as opportunities for state, federal, and industry leaders to discuss the future of semiconductor research, development, and workforce development. The university's CHIPS & Science Act Task Force dissolved soon after the October 2023 workshop, as the Semiconductor Institute would be assuming responsibility for coordinating and facilitating efforts to enable the resurgence of the US semiconductor manufacturing industry and leadership.

In addition to the descriptive analysis, qualitative data collection and analysis informed the DBR approach to the three CHIPS & Science Act workshops. Research study participants varied across the three workshops, with 21 respondents in the first workshop (June 2023), 11 in the second (August 2023), and 12 in the third (October 2023). Study participants represented various disciplines related to semiconductor research and development, including but not limited to electrical engineering, materials science, and computer science. The key findings reported in Table 2 relate to participants' perceived effectiveness of each workshop.

Study participants consistently reported positive experiences with collaborative activities across all three workshops. Small group work was highlighted as particularly effective in fostering collaboration, with a little over half of respondents in Workshop One reporting positive experiences in small group sessions. For example, one participant stated, 'the small group was also very

WORKSHOP NUMBER	TIMEFRAME	HOSTING UNIT	SCOPE	ATTENDANCE	DELIVERY
One	June 2023	Institutional Task Force	Institutional stakeholders	81	Online
Two	August 2023	University System Research	University System stakeholders	142	In-person
Three	October 2023	University System Semiconductor Institute	State stakeholders	242	Hybrid

Table 1 Descriptive analysis across three workshops.

SURVEY QUESTION THEMES	WORKSHOP 1	WORKSHOP 2	WORKSHOP 3	EMERGENT THEMES
Positive experiences with collaborative activities	60%	80%	75%	Interdisciplinary collaboration forming, networking
Effectiveness of learning design and facilitation	70%	100%	90%	Structured facilitation and effective hybrid delivery
Building capacity	50%	80%	80%	Increased confidence and research readiness
Limitations	67%	63%	75%	Time constraints

Table 2 Qualitative themes across three workshops.

informative. We developed good ideas and discussed a variety of topics.' The in-person format in Workshop Two received the most positive feedback regarding collaboration. The majority of respondents mentioned improved networking opportunities, as described by a participant: 'One of notable outcomes of the workshop was the opportunity for extensive networking. This outcome reflects the exceptional proficiency and dedication by the organizing team.' Despite the hybrid format of Workshop Three, a large number of respondents reported valuable collaborative experiences. One participant noted the benefits of interdisciplinary interactions when they 'got to meet and talk with many people from [different] industr[ies] and other universities. It was a wonderful event to meet and know people with different backgrounds.'

The workshops demonstrated varying levels of effectiveness in facilitating knowledge sharing. In Workshop One, many participants reported gaining new insights into the CHIPS & Science Act and its implications for their research. One respondent described this as follows: 'basic background information helped me better understand the intent and general scope of the universities CHIPS and Science Act.' Workshops Two and Three revealed improved knowledge sharing when compared to the baseline responses of Workshop One. Participants frequently mentioned specific examples of knowledge gained from peers and presenters, such as, 'hearing from [institutional] leadership as well as representatives from government and industry is helpful.' Multiple Workshop Three participants also reported valuable learning experiences, particularly in understanding interdisciplinary approaches to semiconductor research.

The workshops' effectiveness in building capacity among participants was evident in several areas. Some participants reported feeling more prepared to engage in CHIPS & Science Act-related research initiatives, as a Workshop One participant stated: 'the overviews of the semiconductor ecosystem in [state] and the particular possible applications of the CHIPS and Science Act at this university were extremely helpful.' This sentiment appeared to increase in subsequent workshops, with participants specifically mentioning an enhanced understanding of funding opportunities and collaborative research strategies. Workshop Three showed a high level of perceived capacity building, with many participants reporting increased confidence in their ability to contribute to semiconductor research and education initiatives.

While the workshops were generally well-received, participants identified several challenges. Time management was a consistent issue across all three workshops, with many participants suggesting better time allocation for different activities. Workshop One, which was virtual, received mixed reviews, with some participants reporting that being online hindered their full participation because '[it] is always tough to stay engaged during virtual meetings.' For Workshop Two, which was in person, a few participants mentioned that the full-day format was exhausting and suggested splitting the content over multiple days. However, one participant suggested that 'facilitating opportunities for participants to further interact and network during the evening would be beneficial.' In Workshop Three, which had a hybrid format, participants noted challenges in equally engaging online and in-person attendees during collaborative activities.

DISCUSSION

The increasing attendance numbers across the three workshops suggest that format plays a crucial role in engagement. The most attended was the hybrid format of Workshop Three, which aligns with recent research on the flexibility and accessibility of online professional development (Gacs et al. 2020). However, the in-person and/or online workshops, while having lower attendance, demonstrated increased effectiveness in fostering collaboration and networking as the initiative unfolded. For example, one participant identified value in the 'plenary presentations…and networking.' The positive feedback on small group work and interdisciplinary interactions across all workshops underscores the importance of interdisciplinary and collaborative learning experiences (Tang & Pei 2023; Patterson et al. 2019; Clark et al. 2024). The challenges identified by participants, particularly regarding time management and the difficulties of engaging both online and in-person attendees in hybrid formats, highlight areas for improvement. These findings echo broader discussions in the literature about the complexities of designing effective hybrid learning environments (Raes et al. 2020).

The overall trend of increasing effectiveness across the three workshops supports the value of sustained, iterative faculty and/or research development initiatives. This research suggests that one-off workshops are less effective than ongoing professional development programs (Darling-Hammond et al. 2018). The CHIPS & Science Act workshops appear to have created a nascent community of practice around semiconductor research at a case study institution, potentially laying the groundwork for long-term collaboration and innovation (Wenger 1998), or, as a participant described it, a 'great opportunity to learn more about CHIPS and the people at [the institution] that are working in this space.' The workshops appear to have successfully created a space for legitimate peripheral participation (Lave & Wenger 1991; Rude 2023), allowing participants to engage with the broader community of semiconductor research and gradually move towards full participation. For example, one participant wrote, 'I was an observer and listener at this workshop. I learned quite a few new things about semiconductors and met people involved in these efforts.'

From a theoretical perspective, the workshops' success in fostering collaboration and knowledge sharing aligns with the four learning theories. According to Rude (2023), Social Constructivism is important to the stakeholder networks, relationships, and processes associated with the CHIPS initiative. Participants were able to construct new knowledge individually and collectively, building on their prior experiences and interactions with peers (Rude 2023; Piaget 1952; Vygotsky 1978). The reported increases in confidence and preparedness to engage in CHIPS & Science Act-related initiatives suggest that transformative learning (Mezirow 1991) may have occurred for some participants, as they developed new perspectives and frames of reference. One participant described this realization as follows: 'it was an interesting experience for me—seeing the political side of the science & engineering enterprise.' The consistent workshop emphasis on social interaction in knowledge construction indicates the presence of social constructivist theory (Vygotsky 1978; Windschitl 2022; Rude 2023). After participation, faculty are equipped to create smaller-scale changes within their research, teaching, and collaborative environments (Patterson et al. 2019; Rude 2023; Finn & Feldhaus 2022). The notion of faculty ownership or buy-in in the initiative was present, with one participant expressing gratitude for now 'having information about [the Semiconductor Institute] and future workforce development plan(s) for my institution.' The workshops provided opportunities for faculty and industry leaders to connect, which has the potential to result in additional collaborative learning experiences like research, internships, and course development (Bozic & Dunlap 2013).

The study's findings offer several practical implications, including ten workshop design considerations. First, the findings suggest that a design-based research and case study approach to educational development workshops can be effective (Donaldson et al. 2021; Barab & Squire 2004). This multifaceted and qualitative approach to data collection allowed for a thorough examination of participants' experiences and the effectiveness of the workshop design (Creswell & Poth 2018). The workshop and DBR approach leveraged the strengths of online, in-person, and hybrid modalities, and accommodated the varying needs of participants. Similarly, this study demonstrates the value of iterative design-based research to improve workshop effectiveness over time (Donaldson et al. 2021; Barab & Squire 2004). Future iterations of the workshops could benefit from strategies to better balance activities and ensure equitable participation across different modes of attendance. The results also highlight the importance of interdisciplinary collaboration in addressing complex research challenges, such as those posed by the CHIPS & Science Act. The diversity in participants' disciplinary backgrounds was intentional, to foster interdisciplinary collaboration and knowledge sharing (Rude 2023). Lastly, this research, and especially the outcomes of research collaboration(s) initiated as a result of workshop participation, may inform and strengthen the United States semiconductor industry, and maintain the nation's competitive edge in this critical sector.

Ten workshop design considerations:

- Workshops can incorporate activities that encourage participants to examine and question their existing assumptions about research, collaboration, or their field of study.
- Utilize a flexible learning experience design involving different formats to accommodate the varying needs and circumstances of the learner(s).
- Incorporate learning theory as a foundational element of the design of learning experiences as part of either curriculum or professional development.
- Include explicit and organic networking time and spaces for all participants.
- Encourage and prompt reflection activities pre-session, in-session, and post-session.
- Be patient, as not every participant is an active learner. Some participants may observe and reflect prior to actively engaging.
- Design learning experiences that generate thought-provoking and collaboration-forming moments around new ideas, frameworks, and paradigms.
- Remember that stakeholders (even academics) are leaders, learners, and cultivators of change.
- Consider that collaboration often begins with a conversation. Creating opportunities for industry to connect to the research enterprise (including faculty and students) is important. This should also build

in continued opportunities for engagement and collaboration forming.
- Develop and practice group agreements that promote meaningful and respectful discussion

However, this research has limitations that should be acknowledged. The case study approach, in particular the relatively small sample size and the focus on a single institution, limits the generalizability of the findings. Additionally, the reliance on self-reported data through open-ended surveys may not capture the full range of workshop outcomes and participant experiences. Future research could benefit from including objective measures of collaboration and research output, as well as longitudinal studies to assess the long-term impact of such initiatives. For example, additional research could investigate the extent to which collaborations were successful in semiconductor research, funding, and overall collaboration.

CONCLUSIONS

By examining the outcomes of these workshops, this case study research contributes to the broader understanding of how universities can effectively mobilize their intellectual resources in response to national initiatives like the CHIPS & Science Act. This study provides insights into the design and implementation of educational development initiatives and offers valuable lessons for other institutions engaged in similar efforts. The four learning theories provided a robust theoretical foundation for designing three-phase educational development workshops. By incorporating elements from Situated Learning (Lave & Wenger 1991; Wenger 1998), Cognitive Constructivism (Piaget 1952), Social Constructivism (Vygotsky 1978), and Transformative Learning (Mezirow 1991), the workshops created rich learning environments that supported the complex needs of stakeholders engaging with emerging CHIPS & Science Act research efforts. Or, as described in one participant's reflection, 'we had good discussions about workforce development for semiconductor manufacturing, from undergrad to grad to training, and the mechanisms that we can use to provide that for the industries in [state].'

The CHIPS & Science Act outcomes and workforce shortage point to a need for a 'coordinate[d] effort among government agencies, industry, and educational institutions' (Gunarathne & Chaitanya 2024, p. 66). In the context of the expected broadening of the semiconductor industry, this case study showcases the potential for such initiatives to foster collaboration, knowledge sharing, and capacity building among faculty and researchers. In conclusion, this research provides valuable insights into the design and implementation of educational development workshops in response to national research priorities. As universities continue to play a crucial role in addressing national and global challenges, the lessons learned from this study can inform future efforts to mobilize academic expertise effectively.

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COMPETING INTERESTS

The authors have no competing interests to declare.

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