Osazuwa Okundaye Santos osazuwa-okundaye-santos.com awuzaso@gmail.com,awuzaso@tamu.edu

Research Statement

Electronic digital computing has evolved from room-scale machines to omnipresent devices that mediate how we work, learn, and define ourselves. Ideally, computing should augment our ability to process information so seamlessly that it fades into the background, becoming as essential and invisible as the air we breathe. However, this invisibility persists only as long as the interaction model remains reliable. When interaction design breaks, the experience of effortless extension fades, revealing that we are merely manipulating a machine. This disconnect highlights a fundamental challenge in interaction design: **how can real-world phenomena be computationally represented?**

Computing is a medium that translates real-world data into digital representations via layers of computational abstraction. Breakdowns in interaction occur when computational representations fail to align with human cognition. Therefore, computer-interaction design is not merely a technical challenge but a *"philosophical commitment"* to how we represent reality. Adopting the lens of Embodied Interaction [1], my research moves beyond abstract formalizations to examine how technology is grounded in everyday, mundane experiences. By studying how users practices and technology adoption arise in everyday life, I aim to design systems that fit the physical, social, and contextual realities of the world.

My research investigates the co-evolutionary design of between human experience and computational systems. I employ a hybrid methodology combining human-centered design, computational modeling, and digital fabrication to pursue four interrelated research programs: 1) Modeling and augmenting human cognitive processes; 2) Developing tangible interfaces to bridge virtual and material environments; 3) Advancing engineering education through making-based learning; and 4) Analyzing dataset bias in generative AI tools and its implications as a design tool for architecture, engineering, construction practice.

RESEARCH DIRECTIONS

Supporting Contextual Workflows through Episodic Memory

For many of us, those whose work is centered around personal computers, routinely juggle multiple ongoing projects. We manage these multiple projects by relying on both digital and physical artifacts (i.e., notes, files, window arrangements) that are associated with our work [2-5]. Our collected information acts as cues, helping us remember goals, stay continuous, and resume suspended tasks . Yet, modern computing environments fragment these cues across applications and media, making it difficult to recover not only needed resources but also the mental context that anchors project identity and ongoing progress. My dissertation, informed by cognitive psychology, explored how the environment helps us remember past project details when switching and resuming work on a computer. Specifically, I sought to understand how computational representations of working contexts can be better designed to cue resumption, reduce reconstruction work, and support attention across transitions.

To answer these questions, I conducted a series of studies examining how working contexts are created, maintained, and resumed across media [6]. In the first study, an office-like digital task environment revealed that cues such as spatial window structure, tabs, and hyperlink traces substantially reduce mental workload and reconstruction effort during task resumption. When these cues disappeared, participants resorted to cognitively costly strategies like re-reading or re-searching. A second study compared in-person and teleconference meeting contexts, showing that physical movement, embodied cues, and shared artifacts in co-present environments anchor mental transitions more effectively than Zoom's flattened spatial structure, despite lower subjective workload online. Together, these findings show that context reinstatement is a process shaped by visual persistence, spatial transitions, and environmental structure.

Building on these insights, I designed, implemented, and evaluated the Working Context Manager (WCM) [7], a tangible system that connects RFID-tagged physical objects to digital working contexts **(Figure 1)**. Presenting a card retrieves a project's digital resources and restores their prior state, allowing the physical proxy to externalize episodic memory and anchor attentional cues. In deployment, participants naturally inscribed, organized, and manipulated the cards as cognitive artifacts, achieving faster, deliberate transitions and reduced reconstruction work compared to digital-only tools. This work demonstrated how tangible–digital hybrids can represent abstract digital contexts, suggesting how designing context-aware productivity systems/environments can support cognitively demanding, multi-project workflows.

Making through Micromanufacturing: Situated STEM Learning

Many students, particularly in rural and underserved communities, rarely encounter STEM learning experiences that can directly translate into practice outside of the classroom [8-11]. Typically, Making has been recognized as a means to provide such experiences for students, but often these same experiences are limited to Makerspaces or instructional kits. One particular change of these instructional kits is that they are designed first to facilitate its use in the classroom. Often these kits abstract away the material and procedural knowledge that underpins engineering practice. To address this issue, I argued that the benefits of STEM learning in Making can be brought to the forefront by tying Making towards a motivating, productional goal. In production, this would entail real materials, fabrication constraints, hands-on production, and clients with expectations. Collaborating with faculty and students across the disciplines of education, computer science, and production engineering, I lead an initiative to reframe Making and STEM learning through micro-manufacturing: a pedagogy where students work with real tools, physical materials, and production processes to fabricate objects for authentic clients [12-15]. This material-centered approach positions Making not as an isolated activity but as a craft-oriented, iterative workflow that reveals how design, fabrication, and engineering thinking emerge through engagement with physical artifacts [16-18].

To investigate how material practice shapes learning, I developed a two-year curriculum that embedded 3D printing, assembly, prototyping, and quality control into a classroom environment. I lead development of a horizontal learning based curriculum for high-school CTE classes across the subjects of: 1) Micro-controller based electronics; 2) Programming; 3) 3D design & fabrication; 4) Production/manufacturing engineering. To evaluate this curriculum, my team partnered with independent school districts across Texas (Bruni ISD, Jim Hogg County ISD, and Bryan ISD). With each school district, I taught under-graduates to teach daily classes to high-school for real design and production exercises. In assessing the impacts of my developed curriculum, I collected classroom data and analyzed the impacts of a horizontal learning based curriculum towards outcomes including engineering understanding, broad knowledge acquisition, and development of engineering/STEM self-concept and identity.

Students in the daily classes produced deliverables for real stakeholders (e.g., educational kits for partnered elementary schools within the same school district), requiring them to negotiate timelines, organize production lines, and iterate based on the physical behavior of their prototypes (**Figure 2**). Through surveys, weekly self-efficacy measures, and recorded observations of production cycles, I examined how students internalized material reasoning and production-oriented problem solving.

Findings showed significant gains in engineering and Making self-efficacy, with students identifying material constraints and fabrication errors as opportunities for discovery rather than failure. Peer-to-peer instruction naturally emerged around material troubleshooting (e.g., adjusting printer settings, re-designing 3D files, testing tolerances and quality) highlighting how material engagement fosters collaborative knowledge building. By situating STEM learning in real production workflows, the project demonstrates how materiality can anchor pedagogical design: when students work directly with physical systems, they develop confidence, agency, and a deeper understanding of how materials and engineering concepts arise.

Mechanical and Sensing Affordances in Kerf-Inspired Metamaterials

Digital fabrication technology has democratized the means for everyday users to design and implement their ideas for functional objects for everyday use. One such form of technology, laser cutting, enables kerfing as a fabrication technique to engineer compliant, yet structurally robust materials. However, owing to the technical challenges in operating laser cutters, kerfing has a limited audience to access its design benefits. To address this limitation, I was interested in how 3D printing, another more easily accessible form of digital fabrication, can broaden this design technique for a wider audience. Through 3D printing, kerf geometries can be reinterpreted as functional microstructures that tune the mechanical performance of printed objects. By fabricating kerfed materials through 3D printing, this raises a broader HCI–materials question: how can material behavior—programmed through geometric structure rather than hardware—serve as an interaction substrate? My work investigated how adapting kerf patterns into deformable 3D-printed mechanisms whose flexibility, elasticity, and tactile character can be systematically controlled [19].

Through empirical design studies, I mapped how geometric and material parameters, such as kerf topology, cut density, thickness, and PLA–TPU bilayer composition, can influence kerf geometry behavior. I found that small adjustments to kerf microstructure can produce large differences in user-perceived responsiveness and compliance, and that increasing cut density or using softer material layers enhances deformation while thicker or sparsely cut structures stiffen the response. My findings suggest how kerf structures function as programmable mechanical elements: their deformation can be tuned predictably for in-plane bending, out-of-plane twisting, or compound motion.

Using these insights, I developed design guidelines and a series of interactive prototypes (e.g., push buttons, sliders, dials, wearable sensor bands, and soft robotic grippers) **(Figure 3**). In these devices, mechanical behavior becomes an interaction resource: kerf cells amplify deformation locally, enable smooth and expressive motion, and support embedded sensing through simple additions such as Hall-effect sensor–magnet pairs. Altogether, my work in 3D printed kerf structures demonstrates how this approach to kerfing provides low-cost, customizable, and assembly-light interfaces.

The Latent Space of Architectural Typologies via Generative AI

Generative AI systems in AEC (Architecture, Engineering, Construction) inherit structural asymmetries from web-scale datasets (e.g., Common Crawl), often excluding rural or culturally peripheral regions. To interrogate these dynamics, I collaborated with architecture researchers and lead a team of undergraduate architecture researchers to construct a multi-scale, multi-modal dataset of Texas housing photographs across rural, suburban, and urban regions. We contrasted our dataset with architectural housing examples from major U.S. megaregions. After amassing our dataset, we used both Midjourney's and Dall-E's generative image capabilities to examine how groups of housing regions were interpreted and understood, visually and textually. We had performed our analysis through passing our images through multiple rounds of model reinterpretation, generating more than 3,000 synthetic images and 12,000 AI-produced textual descriptions (**Figure 4**).

In interpreting the generated outputs, we had used three types of measures. First, by embedding these outputs in CLIP's multimodal latent space, I quantified how semantic meaning drifts as a function of geography, finding significantly lower alignment for rural contexts. Second, through ORB key point matching and FID, I was able to qualify and quantify what systematic distortions in spatial structure arose in subsequent generations of housing images. Together, these measurements reveal not just aesthetic differences but epistemic ones: ***diffusion models reconstruct urban environments with confidence, yet "hallucinate" rurality into idealized or stereotyped forms.***

Our study contributed one of the first quantitative audits of geographic bias in AEC diffusion models and introduced a reproducible analytic workflow for evaluating representation gaps in generative systems. More broadly, it demonstrated how latent space behaviors encode and reproduce long-standing spatial inequities, with implications for automation pipelines in AEC, for the legitimacy of AI-generated visual evidence, and for community-scale decision-making tools.

FUTURE WORK

We possess unprecedented computational power, yet the "data explosion" powering modern AI often widens the gap between computational representation and human reality. Generative models, trained on stochastic internet data, often lack inherent understanding of the physical world. To address this, my future research aims to bridge the gap between **material intelligence** and **generative computation**, exploring how embodied interaction can create systems that are not only powerful but meaningful.

Theme 1: Contextually Aware, Embodied, Cognitive Partner Systems

My prior work treated context as something to be explicitly represented and stored. I want to explore the design space to consider how systems can sense, learn, and adapt to the emergent, social situations of work.

- **Context as an Embodied Ecology:** Through ubiquitous sensing, I aim to model context as a dynamic, multi-dimensional space comprising place, people, time, and notions of space/place. I want to investigate how a system can interpret numerous environmental cues as switch triggers for to inform how users can traverse their own personal information spaces.
- **Embodied, contextual AI assistants:** Moving beyond disembodied LLMs, I will investigate how multimodal architectures (vision, audio, motion) can ground predictions in sensor-derived experience, allowing AI agents to develop an implicit understanding of what are the various contexts that users are situated in.

Theme 2: Kerf-Based Metamaterials for Embodied Sensing and Actuation:
I will extend my research on metamaterials toward smart, computationally designed structures that sense and respond to bodily dynamics.

- **Kerf-Based Proprioception:** I want to explore the development of 3D-printed kerf sensors combining resistive and capacitive sensing to track complex multi-layered deformations. By fusing sensor data with ML models, these materials will enable wearables that interpret body states (joint angles, muscle contraction) via material deformation rather than optical tracking.
- **Mechanical Propagation:** I will explore kerf surfaces as passive actuators where local forces propagate to produce global movement. This includes nonplanar structures converting vertical force to lateral expansion, enabling soft robotic grippers and shape-changing wearables without external motors.
- **Computational Design Tools:** To democratize fabrication of interactive, 3D printed objects, I aim to build tools that can generate kerf patterns and guide sensor placements based on desired interaction goals. The goal would be to provide an interface abstraction layer over CAD-CAM design and FEA simulation that could provide tight linkages between users' expected input forces and output action to reduce cycles of re-design and testing.

Theme 3: AI-Enabled Micromanufacturing and Making Education
My future work seeks to support education environments through generative AI that is informed by student-teacher learning dynamics.

- **AI as a More-Knowledgeable-Other (MKO):** In my work on building communities of practice in Making [17] , I introduced a framework on how students develop gradual mastery through partnered activity with peers and teachers, these being referred to as 'more knowledgeable others' (MKOs). I want to propose a design for agentic generative AI tutors embedded in the Making process. These agents, can work with students to scaffold troubleshooting and help students articulate misconceptions. The agents can be personalized for each student and be collectively connected to a teacher to gain a holistic view of recurring issues and adjust instruction.
- **AI Literacy via Fabrication:** By integrating generative AI into hands-on making, students can build a practical understanding of intelligent systems. I aim to position AI as a collaborative partner that encourages productive struggle rather than replacing human judgment. Crucially, this approach teaches students to recognize the AI's limitations, fostering critical thinking and the habit of verifying generated results.

CONCLUSION

My work aims to build computational systems grounded in the realities of everyday life. By combining contextual sensing, fabrication, and human-centered AI, I develop technologies that enhance human capability and broaden access to engineering. Ultimately, I seek to create intelligent systems that are deeply aligned with human experience—responsive to our context, respectful of our agency, and attuned to our environments.

FIGURES

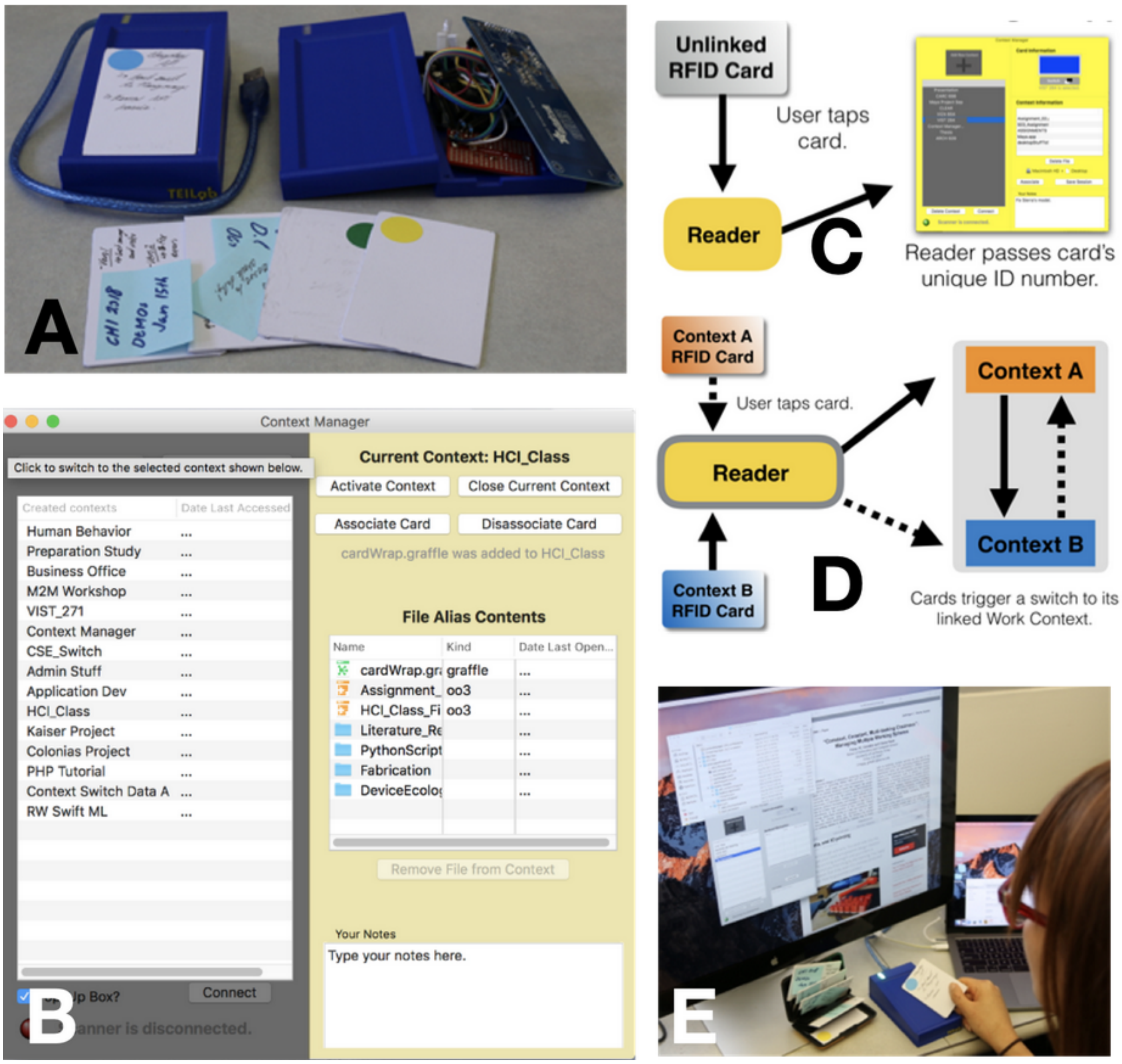

Figure 1: The 'Working Context Manager System' (WCMS) comprises a hardware RFID card subsystem (A) and a light-weight software component (B), used together for the interaction design for context switching across different represented projects (working contexts) (C). A card reader paired with a created working context allows the users to associate RFID context cards to their work contexts and recall them in their original state (D and E).

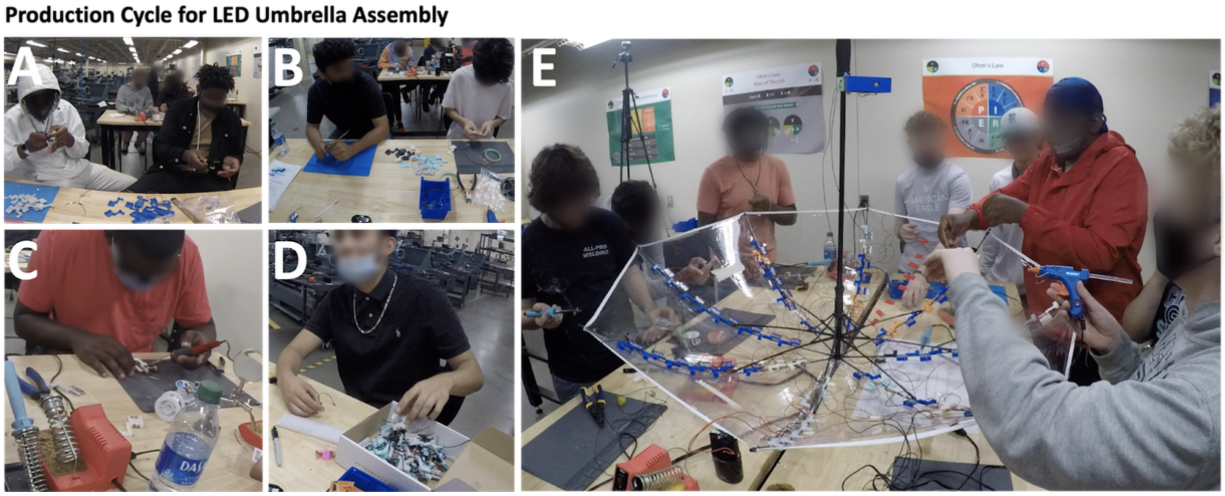

Figure 2: High school CTE students develop a production pipeline to manufacture educational kits for use with a partnered elementary school. **A)** Copper-tape is cut and applied to pre-processed 3D-printed LED connector parts; **B)** Jumper-wires are cut and LEDs are inserted into the LED connectors; **C)** LEDs and jumper-wires are soldered to the copper tape on the connector; **D)** Quality-control testing on individual soldered LED connectors. Table adds approved connectors to stock or send them back for repair; **E)** Students solder together the individual LED connectors while ensuring proper electrical connections for power, ground, and control by an Arduino MEGA microcontroller.

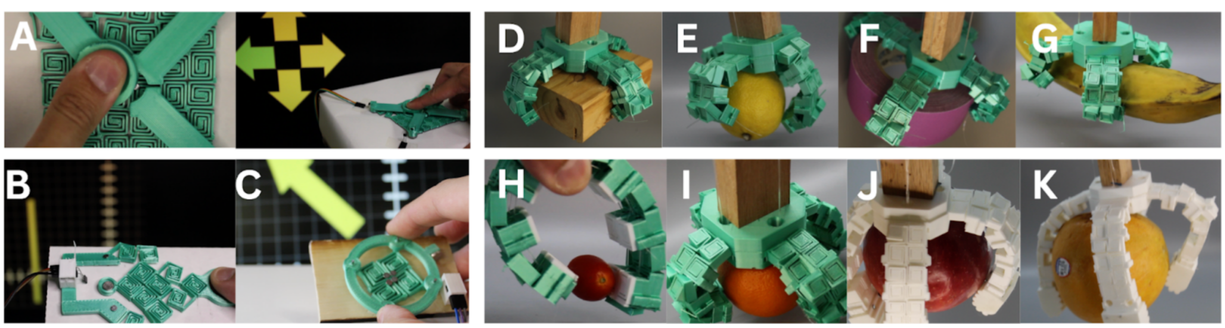

Figure 3: 3D printed kerf structures support various interaction affordances, a slider controller (A), a pinball-type spring input device (B), a rotational dial (C), a four-finger gripper that handles objects of different shapes, sizes, textures, and weights (D–G). Modifying various geometry and material parameters, the gripper modifications become a two-finger gripper with a TPU top layer, for small cherry tomatoes to tangerines to slippery apples to large, heavy grapefruits using TPU-based claws (H–K). Video available here.

Figure 4: Diffusion models like Midjourney are known for the quality of their generated images. The quality of these images are based on the proprietary diffusion models that are trained on large corpus of image and text data available on the internet. While the images themselves are realistic, when used in the context of architects and designers for visualization and ideation, the results may not align to reality. Above are 4 different listings that were presented to Midjourney (Original Photo) and responded with generated text descriptions. These text descriptions were fed back to Midjourney, generating four generated images and additional text descriptions. Through this workflow, we were able to account for how the model understands the typology of listings based on its training data. Our results yielded the following: First, upper class housing listings tend to preserve their structure while middle class listings tend to shift towards a style typical of upper class typologies. Second, lower class, low-income housing tends to lose its structure, exaggerating or introducing themes of degradation in its reconstructions.

REFERENCES

1. Dourish, P., *Where the action is*. 2001: MIT press Cambridge.
2. Gonzales, V. and G. Mark. *Constant, Constant, Multi-tasking Crazines*. in *Proceedings of CHI*.
3. Kidd, A. *The marks are on the knowledge worker*. in *Proceedings of the SIGCHI conference on Human factors in computing systems*. 1994.
4. Mark, G., *Multitasking in the digital age*. 2022: Springer Nature.
5. Mark, G., D. Gudith, and U. Klocke. *The cost of interrupted work: more speed and stress*. in *Proceedings of the SIGCHI conference on Human Factors in Computing Systems*. 2008.

6. Okundaye, O.J., *Mental Context Reinstatement in Digitally Represented Work through Computationally Augmented Physical Artifacts*. 2024.
7. Okundaye, O., et al. *Facilitating context switching through tangible artifacts*. in *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems*. 2017.
8. Berman, A., et al., *Proximal and Distal Mentors: Sustaining Making-Expertise in Rural Schools*, in *Proceedings of FabLearn 2019*. 2019. p. 26-33.
9. Hordemann, G., et al. *Everybody needs somebody to teach: Embodiment, telecommunication, and telepresence in stem learning*. in *2020 ASEE Virtual Annual Conference Content Access*. 2020.
10. Okundaye, O., et al. *Telepresence robotics for hands-on distance instruction*. in *Proceedings of the 11th Nordic Conference on Human-Computer Interaction: Shaping Experiences, Shaping Society*. 2020.
11. Okundaye, O., F. Quek, and S. Chu. *Broadening participation for remote communities: Situated distance telepresence*. in *Proceedings of the 18th ACM International Conference on Interaction Design and Children*. 2019.
12. Okundaye, O., et al. *From making to micro-manufacture: Catalyzing stem participation in rural high schools*. in *Proceedings of the Conference on Creativity and Making in Education*. 2018.
13. Okundaye, O., et al., *Making STEM real: the design of a making-production model for hands-on STEM learning.* European Journal of Engineering Education, 2022. **47**(6): p. 1122-1143.
14. Okundaye, O.J., et al. *Motivating STEM Participation through a'Making as Micro-manufacture (M3)'Model*. in *2018 ASEE Annual Conference & Exposition*. 2018.
15. Qiu, S., et al. *'All Together Now'-Integrating Horizontal Skills in CareerTechnical Education Classes with Making and Micro-manufacturing*. in *2022 ASEE Annual Conference & Exposition*. 2022.
16. Okundaye, O.J., et al. *Making in The Colonias: Motivating STEM Participation through a Making as Micro-Manufacturing Model*. in *2020 ASEE virtual annual conference content access*. 2020.
17. Okundaye, O.J., et al. *Developing communities of practice through peer mentorship in making through micro-manufacturing model*. in *2019 ASEE Annual Conference & Exposition*. 2019.
18. Okundaye, O.J., et al. *How Deep is Your Knowledge? Consideration to the Breadth and Depth of Knowledge of CAD/CAM in M3-powered Technology CTE Classes*. in *2021 ASEE Virtual Annual Conference Content Access*. 2021.
19. Okundaye-Santos Jr, O.J., et al. *3D Printed Kerf Structures*. in *Proceedings of the Nineteenth International Conference on Tangible, Embedded, and Embodied Interaction*. 2025.