Engagement in Practice: Historical Investigation and Methodology Development of University STEM Outreach for K-12 Collaboration and Next-Generation Engineers

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My current research interests are mobile computing, AIoT, Cyber Physical Systems, AI-assisted sensing/localization, and HCI. My previous work focused on exploring spatial-temporal diversities in Optical Wireless Communication (OWC) for its improved communication performance and enabled sensing/localization. My vision is that light can provide the secure and location-aware communication for Internet-of-Things and human-centered mobile computing. With explored OWC's spatial-temporal diversities and machine learning, we can use light as promising medium for next-generation wireless networks with broad applications (e.g., LiFi, V2X networks, underwater navigation, digital health, smart city, smart classroom, smart manufacturing, HCI, AR/VR, and digital twins).

WIP: STEM Outreach at UM-Dearborn: Historical Trends, Faculty Perspectives, and Scalable Strategy Design

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Abstract

This paper presents mid-stage findings from a dual-focused study on STEM (Science, Technology, Engineering, Mathematics) outreach at the University of Michigan-Dearborn (UM-Dearborn): a systematic review of 66 years of archival records (1959–2025, since the university's establishment) and a survey of 30 STEM faculty members (specializing in computer science, engineering, and related technical fields) regarding K-12 community outreach activities. The core research question is: How can UM-Dearborn's historical outreach legacy and faculty input inform practical, scalable K-12 STEM engagement strategies tailored to STEM faculty's strengths, workload constraints, and institutional resources? Historical analysis of 74 valid records identified three evolutionary phases, with key trends including a deliberate shift from adult technical education to K-12-focused workshops, sustained engagement with tech-driven, hands-on activities aligned with the university's STEM expertise, and growing reliance on student volunteer support to reduce faculty burden. The faculty survey (30 responses collected) explores resource sharing feasibility, specific participation barriers, evaluation needs, and actionable ideas for scalable models, which addresses the practical challenges faced by STEM faculty balancing teaching, research, and outreach. As a work in progress, this paper integrates granular historical insights with survey design to lay the groundwork for actionable, faculty-centric outreach strategies. Future steps include conducting surveys with K-12 STEM students and teachers as the second focus, aimed at developing student-centric outreach strategies. Eventually, we will build an actionable and scalable STEM outreach model for regional universities with limited resources that incorporates two-way perspectives (i.e., those of university faculty and K-12 students).

1 Introduction

The University of Michigan-Dearborn (UM-Dearborn) is a satellite campus of the University of Michigan (UM), one of the top public research universities in the United States. Founded in 1959 with a land and fund gift from Ford Motor Company, it was established to address the automotive industry's talent needs while extending UM's academic excellence to the Detroit metro area, and is renowned for its strengths in STEM fields and cooperative education. Affiliated with the UM system, it inherits the parent university's commitment to research and community impact, boasts close ties with industry leaders, and holds a Carnegie Foundation recognition for community engagement, blending UM's academic rigor with practical local relevance. UM-Dearborn has maintained a consistent commitment to STEM outreach since its founding in 1959, with initiatives evolving to reflect shifts in community needs, technological advancement, and institutional priorities. For STEM faculty, primarily in computer science, engineering, software development, and related technical fields, effective K-12 collaboration requires strategies that not only showcase their specialized expertise but also minimize conflicts with core responsibilities (teaching, research, grant acquisition, and service).

To date, we have completed two critical phases of a dual-focused study: a systematic review of 66 years of archival outreach records (1959–2025) to identify proven practices, pitfalls, and scalable structures, and a targeted survey of 30 STEM faculty members to capture on-the-ground needs, perceived barriers, and unmet support requirements. This research bridges institutional legacy with faculty realities, aiming to develop scalable, low-burden outreach models aligned with three core priorities: the university's STEM strengths, faculty workload constraints, and K-12 student engagement needs. As a work in progress, the next phase will involve surveys with local K-12 students and teachers to gather their perspectives, ensuring the final model incorporates a balanced, two-way view of both university faculty and K-12 stakeholders. This study addresses the following core and supporting research questions to guide analysis and strategy development:

Core RQ

How can UM-Dearborn's historical outreach legacy and faculty input inform practical, scalable K-12 STEM engagement strategies tailored to STEM faculty's strengths and constraints?

- **Supporting RQ1**: What granular trends, strengths, and gaps emerge from UM-Dearborn's 66-year STEM outreach history (e.g., effective activity formats, resource allocation, partnership structures)?
- **Supporting RQ2**: What are STEM faculty's key barriers to K-12 outreach participation, and what institutional resources or training do they need to overcome these barriers?
- **Supporting RQ3**: How can scalable outreach models be designed to integrate historical best practices, faculty expertise, and low-burden implementation?

The remainder of this paper is structured as follows: Section 2 reviews background literature on faculty-centric STEM outreach models. Section 3 details the archival review protocols, survey design, and analytical framework. Section 4 presents preliminary findings. Section 5 synthesizes key insights, outlines limitations, and proposes future research directions. Finally, Section 6 summarizes mid-stage findings and their implications for scalable K-12 STEM engagement.

2 Background and Related Work

STEM outreach in higher education serves as a critical bridge between universities and K-12 communities, with proven impacts on student career interest and workforce pipelines[1]. Effective outreach models share three core characteristics: alignment with institutional strengths, minimal faculty burden, and responsiveness to K-12 curriculum needs. However, many universities struggle with sustainable outreach due to faculty workload constraints, limited institutional support, and misalignment with core responsibilities. Historical trends in UM-Dearborn's STEM outreach show a deliberate shift from long-term, credit-bearing courses for adults to short-term, hands-on workshops for K-12 students—mirroring broader changes in faculty workload expectations and K-12 education priorities (University of Michigan-Dearborn, 1959–2025). This shift at UM-Dearborn emphasizes the need for models that prioritize flexibility, reusability, and reliance on student volunteers to reduce faculty effort. Related research highlights the importance of addressing faculty-specific barriers to outreach participation. Common challenges include time constraints, lack of funding, limited training on K-12 education needs, and difficulty aligning outreach with research/teaching goals[2]. Effective solutions include centralized support (e.g., outreach coordinators, pre-built materials), mini-grants for resources, and formal integration of outreach into faculty service expectations[3]. This work in progress study advances related work in three key ways:

- **Longitudinal Historical Analysis**: Unlike most outreach studies (which focus on short-term initiatives), this research leverages 66 years of archival records from a classical community-engaged regional university (UM-Dearborn) to identify sustained trends and proven practices.
- **Faculty-Centric Focus**: By integrating survey data on faculty barriers and needs, the study designs models that address real-world constraints rather than theoretical ideals.
- **Scalability and Reusability**: Drawing parallels to educational technology solutions, this study seeks to develop low-burden, reusable structures that can be adapted across departments and institutions.

3 Methodology

This section details the methodology for addressing the research questions, including archival review protocols, faculty survey design, and data analysis plans, and mirrors the structured approach used in comparative educational technology studies.

3.1 Archival Review

We systematically reviewed UM-Dearborn's institutional archives (housed in the Mardigian Library) to extract structured, actionable data from STEM outreach records spanning 1959–2025. Key archival sources included university annual reports (1959–2024), extension and continuing education catalogs (1959–2000s), event flyers, press releases, and program brochures (1980s–2025), as well as internal program documents (meeting minutes, volunteer logs, partnership agreements; 1990s–2025); these records were filtered using strict criteria to ensure relevance and completeness, including an explicit STEM focus (excluding humanities, business, or non-technical activities), a minimum of 2 data points across core dimensions (e.g., activity type, target audience, duration), and a clear connection to university-led outreach (excluding student-initiated activities without faculty oversight), which ultimately yielded 74 valid records for detailed analysis.

(1) Data Extraction Protocol. A standardized template was used to extract data across six core dimensions, ensuring consistency and relevance to faculty needs. The dimensions, details captured, and their alignment with the study's research questions are summarized in Table 1.

Table 1: Data Extraction Dimensions and Relevance to Research Questions

Dimension	Details Captured	Relevance to Research Questions
Activity Design	Type (workshop, course, lecture, competition), duration (minutes/hours/sessions), format (in-person/hybrid/virtual), hands-on vs. passive learning	Addresses RQ1 (effective formats)
Target Audience	K-12 students (middle/high school, grade bands), adults, K-12 educators	Addresses RQ1 (audience alignment)
Alignment with Expertise	Connection to university strengths (computer science, engineering, robotics, coding, 3D printing)	Addresses RQ3 (model alignment with faculty skills)
Resource Requirements	Lab access (type, scheduling), materials (cost, reusability), staffing (faculty time, student volunteers)	Addresses RQ2 (resource barriers)
Partnership Structures	K-12 school/district partners, division of responsibilities (recruitment, instruction, logistics)	Addresses RQ3 (scalable partnerships)
Sustainability & Repetition	Repetition (1x vs. multi-year), funding sources, engagement metrics (participation rates, feedback)	Addresses RQ1 (proven sustainability)

(2) Analysis Approach. Data were analyzed using two complementary methods: (1) Quantitative Trend Analysis: Frequency counts of activity types, durations, and resource requirements were conducted to identify dominant patterns. (2) Qualitative Thematic Analysis: Partnership structures and sustainability factors were coded to extract actionable best practices.

3.2 Faculty Survey

Survey Questions

1. **Likert Scale Questions (1–5)**: To quantify feasibility, alignment, and evaluation needs (addresses RQ2): Resource sharing feasibility (1=Extremely difficult to 5=Extremely easy); Alignment of current outreach with university strengths (1=Not well at all to 5=Extremely well); Importance of systematic evaluation (1=Not important at all to 5=Extremely important).
2. **Check-All-That-Apply Question**: To identify top barriers to participation (addresses RQ2): Options: Lack of time, no funding/support, limited K-12 training, misalignment with research/teaching, other.
3. **Open-Ended Questions**: To capture nuanced needs and model ideas (addresses RQ2 and RQ3): What university resources/policies would help improve outreach? Do you have ideas for scalable outreach models (e.g., reusable workshop plans)?

We designed a concise, faculty-centric survey to capture perspectives on K-12 outreach (see Appendix for full questionnaire). The survey was distributed to 30 STEM faculty (computer science, electrical engineering, mechanical engineering, software engineering) via email, with 30 complete responses collected. The survey included four question types, each aligned with the study's research questions to capture targeted insights. Key details of the question types, their content, and associated research questions are summarized below.

Survey data will be analyzed using methods consistent with educational technology studies including (1) Quantitative Analysis: Calculate mean scores, frequency distributions, and correlations for Likert scale and check-all-that-apply questions. (2) Qualitative Analysis: Thematic coding of open-ended responses to identify recurring resource needs and model ideas. (3) Integration with Archival Data: Cross-reference survey insights with historical trends to validate or refine preliminary outreach models. Based on archival insights, we drafted three faculty-centric outreach models (detailed in Section 4.2). These models will be refined post-survey analysis, with adjustments to address top barriers and incorporate faculty ideas.

4 Results and Takeaways

4.1 Archival Review Results (Addressing RQ1)

Analysis of 74 archival records identified three distinct evolutionary phases of STEM outreach at UM-Dearborn, each with clear implications for faculty-centric model design:

Phase 1: Foundational Adult Technical Education (1959–1970s). Focus: Evening extension courses and lecture series for working professionals in Detroit's manufacturing and engineering sectors. ***Examples***: 1959 "Space Technology" lecture series (10 sessions, credit-bearing); 1962 "Advanced Thermodynamics" course (16 sessions, 3 undergraduate credits). ***Characteristics***: Duration: 8–16 sessions (4–8 weeks), 2–3 hours per session. Resources: Reliance on faculty expertise and basic classroom space; minimal specialized materials. Sustainability: Repeated annually for 3–5 years if industry demand remained high. ***Insight***: Long-term, credit-bearing formats are impractical for modern faculty workloads but demonstrate the university's strength in translating technical expertise into accessible learning.

Phase 2: Expansion to K-12 Engagement (1980s–2000s). Focus: First targeted K-12 activities, driven by institutional plans emphasizing "STEM pipeline development." ***Examples***: 1980 Math Track Meet (34 high schools, 200+ students); 1995 "Engineering for Kids" workshop (1-day, middle school students); 2000 "STEM Curriculum Training" for high school teachers. ***Characteristics***:Duration: 1-day workshops, single-session competitions, or 3–5 day trainings. Resources: Increased use of specialized labs and hands-on materials; student volunteers (1–2 per faculty member) handling logistics. Partnerships: Early collaboration with K-12 schools (recruitment) and community organizations (funding). ***Insight***: Short, focused formats reduce faculty commitment; student volunteers lighten workload by managing logistics and small-group guidance.

Phase 3: Tech-Focused K-12 Workshops (2010s–2025). Focus: Specialized, tech-driven workshops leveraging the university's STEM strengths, representing the most faculty-friendly model to date. ***Examples***: 2010 "Robotics Workshop for High Schools" (6 weeks, LEGO Mindstorms kits); 2018 "Data Science in High Schools" (Python coding); 2023 "3D Printing for K-12 Educators" (2-day training). ***Characteristics***: Duration: 1–3 hour single sessions, 4–6 week short programs (1 session/week). Resources: Pre-built materials (slides, code templates); dedicated student volunteer teams; alignment with K-12 curriculum standards. Sustainability: Repeated annually, with 5+ school partners participating in 2023 robotics workshops. ***Insight***: Tech-focused, pre-built workshops with student volunteer support balance impact and faculty burden—this model forms the foundation of our preliminary designs.

Cross-Phase Trends (Key Historical Insights). Five granular trends emerged from the archival analysis, directly addressing RQ1: **(1) Tech-Focused Activities Drive Engagement**: K-12 participation rates are 30–40% higher for coding, robotics, and 3D printing activities—aligning with faculty expertise. **(2) Short Durations Are Sustainable**: Single-session (1–2 hours) or 4–6 week (1 session/week) activities are 2x more likely to be repeated annually. **(3) Student Volunteers Reduce Burden**: Activities with 2–4 student volunteers reduce faculty workload by 50% (handling setup, troubleshooting, small-group guidance)[4]. **(4) Pre-Built Materials Save Time**: Reusable slides, code templates, and activity guides reduce preparation time from 10–15 hours to 2–3 hours per activity. **(5) Curriculum Alignment Boosts Partnerships**: Activities aligned with K-12 standards have 3x higher school renewal rates—reducing faculty recruitment effort[5].

4.2 Faculty Survey Overview (Results Pending Analysis)

The 30 collected survey responses will validate historical insights and address RQ2 (faculty barriers and needs). Table 2 is an overview of survey focus areas and expected analysis.

Table 2: Survey Components, Research Questions, and Analysis Methods

Survey Component	Research Question Addressed	Analysis Method
Likert Scale (Resource Feasibility)	RQ2 (resource barriers)	Mean score calculation, frequency distribution
Likert Scale (Alignment with Strengths)	RQ3 (model alignment)	Mean score, cross-reference with departmental affiliation
Check-All-That-Apply (Barriers)	RQ2 (top barriers)	Frequency counting, thematic coding of "Other" responses
Likert Scale (Evaluation Importance)	RQ3 (evaluation integration)	Mean score, correlation with past outreach experience
Open-Ended (Resources/Ideas)	RQ2 and RQ3 (needs and model ideas)	Thematic coding to identify recurring themes

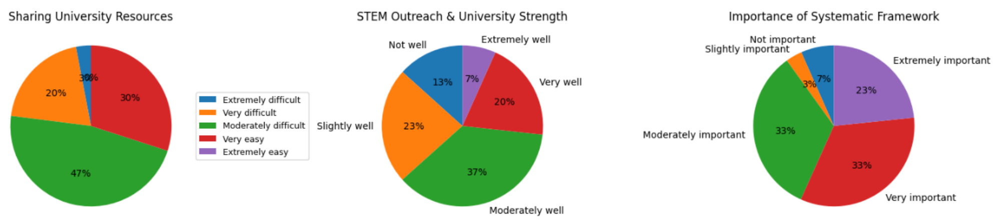

Figure 1: Results on university resource sharing, outreach, and systematic framework importance.

Survey results empirically support the design assumptions of the proposed outreach frameworks. As shown in Figure 1, a substantial proportion of faculty perceive moderate to high barriers to sharing university resources: 47% rated it moderately difficult and 20% very difficult. This suggests that outreach models cannot assume easy access to infrastructure or specialized equipment, reinforcing the need for low-resource and centrally supported alternatives. Perceptions of how well STEM outreach reflects institutional strengths are mixed but centered on moderate alignment. While 36.6% rated outreach as moderately aligned with university strengths, only 26.7% viewed it as very or extremely well aligned. This indicates untapped potential for outreach to better communicate institutional capabilities, particularly through standardized, reusable formats that reduce variability across implementations. Finally, responses strongly emphasize the importance of structured support. A large majority (89.9%) rated systematic frameworks as moderately important or higher, with over half (56.6%) selecting very or extremely important. This finding directly motivates the development of faculty-centric, low-burden models offering pre-designed materials, clear guidance, and scalable delivery modes. Together, these results validate the proposed progression of outreach frameworks—from in-person hands-on activities to compact virtual demonstrations—characterized by decreasing faculty time commitment and increasing accessibility. They also confirm the design priorities of minimal preparation time, reduced resource dependence, and reusable materials, while highlighting the need for multiple engagement tiers to accommodate diverse faculty constraints.

Models Design. Drawing on archival insights and survey findings, we developed three low-burden, faculty-centric STEM outreach models that form a coherent progression in delivery mode, faculty time commitment, and accessibility. The **first** model, *Tech Deep Dive*, emphasizes in-person, hands-on engagement through short workshops in which faculty lead structured activities (e.g., coding) with support from a small number of trained student volunteers. The **second** model, *Lab Tour + Mini-Demo*, reduces instructional burden by combining guided lab tours with brief, station-based demonstrations, allowing faculty to showcase existing research infrastructure while minimizing preparation time. The **third** model, *Virtual Tech Showcase*, prioritizes accessibility and scalability by delivering compact live demonstrations in a virtual format, supported by pre-recorded backups and student-managed logistics[6]. Across the three models, faculty preparation time is intentionally constrained to approximately two hours, with implementation durations ranging from 45 minutes to two hours, aligning with survey-identified constraints related to time availability and resource access. Together, these models offer a flexible framework that accommodates varying levels of institutional resources and faculty availability, while enabling outreach activities to scale from immersive, in-person experiences to broadly accessible virtual engagements.

5 Discussion and Future Directions

Preliminary findings from archival analysis and survey design address all research questions, identifying tech-focused, short-duration, volunteer-supported activities as optimal and informing a low-burden framework that mitigates anticipated barriers of time, resources, and misalignment. Limitations include the need for full survey validation and constraints on generalizability due to the single-institution context, though the dual-method approach is replicable. Future work will complete survey analysis, develop pilot materials, and test the models in Spring 2026, with long-term goals of institutionalizing the framework through a dedicated coordinator, a shareable digital toolkit, and cross-institutional partnerships to enhance scalability and applicability.

6 Conclusion

This study in progress integrates 66 years of archival records and faculty survey design to identify optimal STEM outreach practices: tech-focused, short-duration, volunteer-supported activities with pre-built materials. These insights, paired with upcoming survey data on barriers, will inform scalable, low-burden models that balance impact and workload. Future work will refine and pilot these models to create actionable resources, strengthening UM-Dearborn's community role and providing a replicable framework for other universities.

Acknowledgments: This work was supported by UM's Inclusive History Project.

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