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Bridging STEM Identity and Real-World Application: The Impact of Culturally Relevant Robotics and AI Chatbots on Diverse Elementary-Aged Students (Work In Progress)

Dr. Melissa Carole Richards, Clarkson University

Dr. Melissa C. Richards is an Assistant Professor and the Director of the K12 Robotics Outreach Program at Clarkson University's Institute for STEM Education. She specializes in problem- and project-based STEM education, experiential learning, outreach, and mentorship.

Dr. Richards holds a Ph.D. in Mechanical Engineering. Her research focuses on theoretical rock mechanics and STEM education. She is dedicated to promoting diversity, equity, inclusion, and a sense of belonging for underserved and underrepresented students, particularly in engineering. Furthermore, since 2018, she has served as a Regional Program Delivery Co-Partner for FIRST LEGO League, inspiring young people to explore robotics and engineering.

Dr. Mahesh K Banavar, Clarkson University

Mahesh K. Banavar is an assistant professor in the Department of Electrical and Computer Engineering at Clarkson University. He received the BE degree in Telecommunications Engineering from Visvesvaraya Technological University, Karnataka, India in 2005,

Joshuana Korvie, Clarkson University
Martha Kitui
Katalina Villalba, Clarkson University

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Introduction

Robotics and artificial intelligence (AI) are becoming more common in classrooms and informal learning environments. Yet, most experiences prioritize the technical aspects, such as coding and engineering skills, without addressing the cultural disconnect that students from underserved and underrepresented backgrounds may experience. Numerous studies have shown that initiatives grounded in culturally responsive pedagogy, which emphasize the importance of connecting curriculum to the lived experiences of students, increase engagement and persistence in STEM (e.g., [1], [2]). Furthermore, research suggests that when STEM tools reflect students' identities and lived experiences, learning becomes more meaningful and engaging [3], [4].

Integrating generative AI chatbots enhances information accessibility and engagement, promoting critical thinking and comprehension of complex concepts [5]. Current international policies and research findings further emphasize the importance of ethics and safety frameworks that protect minors' rights, privacy, and developmental well-being [6], [7], [8].

Research has shown that educational robotics in STEM curricula fosters hands-on learning, supports problem-solving, and boosts student motivation [3]. Additionally, longitudinal studies of programs such as FIRST (For Inspiration and Recognition of Science and Technology) Robotics have demonstrated lasting benefits, including increased interest in STEM careers and academic achievement [9], [10]. Research has also investigated the impact of using LEGO products in educational and therapeutic settings [11], [12], [13], [14], [15], [16], [17].

Elementary-aged children are an ideal focus age group, as they are actively forming beliefs about themselves, what STEM is, who participates in STEM, and whether they see themselves as "STEM people" [3], [4]. Hands-on, interactive learning experiences during childhood play a critical role in shaping curiosity, interest, and identity, particularly when students are encouraged to explore, ask questions, and connect learning to their own lives [10], [18], [19]. Research and community efforts have also shown that early traffic safety education, included as part of culturally relevant STEM experiences for young learners, is essential to public health [20], [21], [22], [23], [24]. Here, cultural relevance means intentional collaboration with students, educators, and community members so that STEM initiatives, materials, and dialogue are grounded in students' lived experiences, shaping both engagement and identity development.

Because LEGO-based play is developmentally meaningful and widely accessible, and because children often connect strongly with characters and mascots, transforming a university mascot into a LEGO robot provides a familiar and relational bridge into STEM learning. To the authors' knowledge, there is limited work that examines how culturally relevant robotics might shape early STEM identity and real-world application among elementary-aged learners.

This WIP aims to explore how early exposure to culturally relevant robotics, prosthetic awareness, and AI can enhance elementary-aged students' ability to connect STEM learning to real-world problems and future career pursuits by designing a robot with both educational and cultural significance. This robot is based on the university mascot, the Golden Knight, featuring a LEGO head, two David Aguilar's MK-Hand Solo (5th-generation) Hand-Solo LEGO prosthetic arms [25], [26], and an interactive AI chatbot focused on traffic safety.

Project Design

The research question this study addresses is: How do culturally relevant robotics and AI chatbots influence elementary-aged students' ability to connect STEM learning to real-world problem-solving and future career aspirations? To answer this question, the study is designed to have the following objectives: (1) to assess changes in students' STEM identity, interest, and curiosity after interacting with the Hand-Solo LEGO prosthetic arm and AI chatbot; (2) to evaluate how demographic and socioeconomic factors influence learning outcomes; and (3) to explore how combining storytelling, robotics, and AI can support real-world skill transfer and STEM identification.

The first step of this work is to design and create a robot capable of interacting with students. We have divided the project into three aspects of the robot: (1) the head, (2) the "brain" within, and (3) the arm. These together will provide a robot that has a familiar form, has a movable hand, and can carry on a conversation with a curious student.

As a host site for annual FIRST LEGO League championships, we sought to repurpose the FIRST LEGO League seasonal challenge kit LEGO bricks that students may already have access to through school robotics programs or community competitions. The reuse of existing parts reinforces sustainability and the transferability of learning across settings, builds on students' prior experiences in robotics spaces, and provides a valuable foundation for more advanced design work. With this design choice, the authors highlight to students that resourcefulness, creativity, iteration, and problem-solving are central to being STEM-minded innovators.

The head and arm will be constructed from available LEGO components, and the "brain" will be an AI chatbot specifically trained to converse about traffic and traffic safety. Each component was designed to be culturally relevant, centering representation and identity, community relevance, and ethical responsibility in both technical construction and future instructional implementation. This framing aligns with asset-based, culturally responsive pedagogy by centering youth agency, creativity, and problem-solving. For students engaged in FIRST programs, this approach reinforces the iterative design principles and collaborative ethos they have already experienced. For students without FIRST participation, LEGO serves as a widely recognizable "hook and anchor," providing a familiar and approachable entry point into engineering thinking. The robot functions as a curiosity-driven educational facilitator, modeling how accessible materials, lived experience, and creativity can lead to meaningful innovation. The design details of the three components are described in what follows.

Project Design: Head

The development of the "Golden Knight" is limited to the specific inventory of LEGO Technic components described above. A digital prototyping phase enables precise part tracking, streamlining the physical construction phase. The primary chassis is engineered using interlocked Technic Liftarms, providing the necessary structural rigidity to support the model's internal electronics and exterior cladding. The mechanical integrity of the assembly relies on a strategic selection of Technic pins based on required kinematics. Beyond static structure, the model integrates mechatronic elements to enhance human-robot interaction. By interfacing motion sensors with motors situated behind the eye assemblies, the robot can track environmental movement and rotate its eyes to convey non-verbal "emotive" cues, effectively replacing traditional facial expressions with mechanical articulation. The design of the "head" is shown in Figure 1.

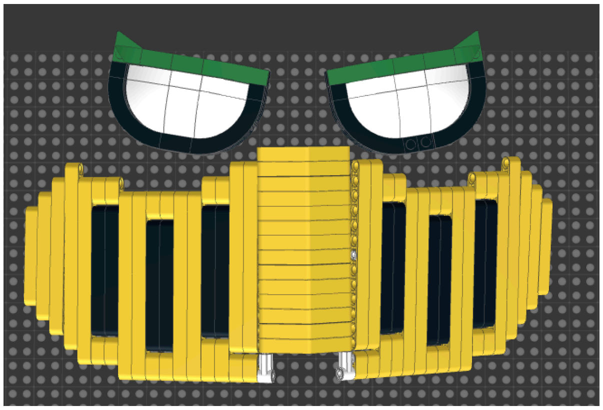

Figure 1. The design of the Golden Knight "Head."

Project Design: Brain

The "brain" of the robot is an AI chatbot trained on traffic safety manuals, child-friendly road safety guidelines, and curated educational materials. Several large language models (LLMs) were evaluated for this purpose, including ChatGPT, Claude, Gemini, and custom GPT variants. A custom GPT (Traffic Buddy) was built using the paid version of ChatGPT.

Table 1. Comparison between ChatGPT, Claude, and Traffic Buddy.

Version	**Strengths**	**Limitations**	**Suitability for Traffic Safety Chatbot**
ChatGPT (free)	Strong reasoning, flexible tone, customizable via GPT Builder	Tends to overuse lists; requires prompt tuning for age-appropriate tone	High, adaptable, and easy to fine-tune
Claude (free)	Paragraph-style responses, strong ethical filtering	Less playful; limited customization options	Moderate, clear but less engaging words
Custom GPT (Traffic Buddy)	Domain-specific training, tailored tone, and safety rules	Requires setup and testing; dependent on base GPT model	Very High, ideal for traffic safety

Traffic Buddy was specifically designed to interact with our audience to ask questions that center on students' own transportation experiences. By ensuring the AI chatbot dialogue with the students is within everyday community realities, the chatbot serves as a culturally responsive facilitator rather than only an informational tool. Results of early testing of existing commercial generative AI systems versus our custom GPT are shown in Table 1.

Furthermore, consistent with international guidance on AI and children, the Traffic Buddy is being programmed to operate within a child-centered safety framework that prioritizes privacy, developmental appropriateness, and human supervision [8], [27], [28]. The chatbot will not collect or retain identifiable student data, and all interactions occur under educator or researcher oversight. Additionally, before interacting with the robot, students will first be taught that AI systems are tools created by engineers and may make mistakes, supporting early digital literacy and critical awareness. Through these measures, the AI component adheres to safety-by-design principles while modeling responsible and ethical AI integration in elementary STEM settings.

Project Design: Arm

The incorporation of David Aguilar's MK-Hand Solo (5th generation) prosthetic design further strengthens the project's culturally responsive foundation. Aguilar reflects on growing up with a limb difference and describes how this lived experience motivated him to iteratively redesign increasingly sophisticated prosthetic arms [29], expanded his efforts to design prosthetic solutions for other youth, and ultimately released his build instructions, parts list, and code as open-source resources, increasing accessibility and global replication [26].

The methodology began with a comprehensive structural review of the MK-V architecture, followed by rigorous inventory management, leading to the identification of critical gaps, specifically components 41677, 87082, and 99773, and procurement through the BrickLink marketplace. Following the consolidation of these technical components, two symmetrical prosthetic units were manually assembled, serving as the primary end-effectors for the robotic system (see Figure 2).

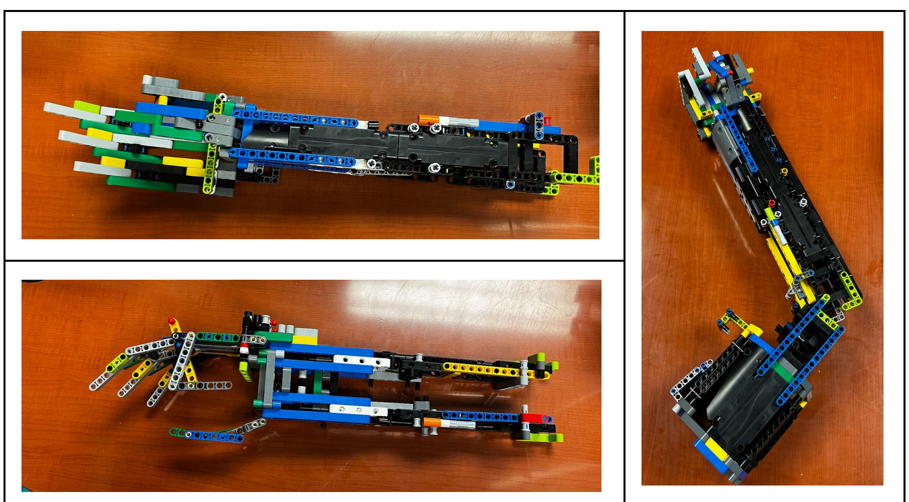

Figure 2. The assembled Golden Knight "hand" prototype.

The subsequent integration phase focused on transitioning from static assemblies to active mechatronic control via the LEGO SPIKE Prime system. The control logic was designed to execute basic grip-and-release cycles through motor-driven actuators. While the structural assembly of the arms was successful, the primary high-torque motor intended to power the arm's lift mechanism exceeded the internal clearance of the prosthetic chassis, and is currently being addressed.

Future Work

Ongoing work will focus on refining hardware integration to achieve reliable mechanical articulation while maintaining accessibility and safety in elementary settings. Upon completion of hardware refinements, the project will transition to Phase 2: finalization of the research design and stakeholder consultation. Before formal deployment, the team will engage local elementary educators, school administrators, community partners, and engineering education experts to gather input on workshop structure, classroom integration, and best practices for ensuring cultural relevance across diverse school contexts. These consultations will help refine instructional framing, confirm alignment with grade-level standards, and ensure that traffic safety discussions reflect the lived transportation realities of participating communities. Feedback gathered during this phase will inform the research instruments and implementation model before submission for full Institutional Review Board (IRB) approval.

As part of Phase 2, one instrument under consideration is the STEM Professional Identity Overlap measure (STEM-PIO-1) [30], a single-item visual format well-suited for elementary-aged students and informal outreach settings, where brief pre- and post-measures are necessary. The STEM-PIO-1 may be paired with short pictorial Likert-scale questions to assess STEM interest and perceived real-world relevance, as well as brief career aspiration questions.

Conclusions

This Work in Progress (WIP) study demonstrates the successful initial integration of culturally relevant robotics and artificial intelligence designed to enhance STEM identity among elementary-aged students. Through Phase 1, the research team has successfully synthesized three distinct technical components: a high-fidelity “Golden Knight” head with emotive capabilities, a domain-specific AI “brain” (Traffic Buddy) optimized for age-appropriate safety education, and two symmetrical LEGO prosthetic arms based on the MK-V architecture. The project confirms that using familiar materials, such as LEGO bricks, provides an accessible entry point for complex engineering tasks while maintaining high student engagement.

The ultimate vision of this research is to synthesize these disparate tools into a single, fully functional “Golden Knight”. This interactive platform will serve as the centerpiece of a comprehensive STEM engagement strategy, designed to foster the imagination and a sense of belonging among young students. By linking high-level engineering concepts to a relatable persona, the project aims to demonstrate how identity-focused design can lower barriers to entry for underrepresented populations in STEM fields.

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