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The Role of Peer interaction and Language Resources in Informal Engineering Learning Environments: The Case for Learning Through Biking

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Abstract

This paper conceptually explores the ideas of peer interaction and language resources in engineering education. Peer interaction is the engagement of students in learning activities with others, leveraging their collective resources, including the languages practices and cultural understandings of their communities. The social dynamics involved in peer interaction, and mediated through language, have the potential to create a supportive atmosphere where learners feel safe to take intellectual risks in STEM-related concepts and practices. Research on peer interaction in informal learning environments, where students may engage in self-directed exploration and experimentation, is critical for understanding the role of everyday activities in engineering education in multilingual and multidialectic contexts. Our work focuses on how language-minoritized learners engage with one another in informal engineering learning environments to make sense of the world around them through their community resources. It attends particularly to social exchanges, such as instances of cooperation, play, and conflict resolution.

Drawing on our understanding of peer interaction and language, our work seeks to conceptually illustrate the opportunities for engineering learning in informal learning experiences focused on bikes and biking for multilingual and multidialectic youth in grades 9-10. Bikes are presented as a design artifact and biking as an opportunity to connect scientific and technical ideas with students' lived experiences. For instance, students may apply engineering design principles, study bike biomechanics, and use the bike to examine their built environment and learn from people. This study emphasizes what theoretical ideas could be used to understand engagement, mentorship and leadership in how peer interaction and language resources may influence students' sense-making of the engineering activities.

Keywords: peer interaction, multilingual and multidialectal learning, language resources, informal learning, biking

Introduction

Peer interaction is defined as the collaborative engagement of students in learning activities, where they articulate ideas, solve problems and understand each other's thoughts [1], [2]. Peer interaction plays a pivotal role in the learning process, particularly in STEM education. In engineering education, peer interactions are crucial for problem-solving and critical thinking, allowing learners to tackle complex challenges through the diverse perspectives different people bring to an activity. Furthermore, relationships among students developed by language uses creates a safe space for students that allows them to take STEM related intellectual risks [3]. While extensive research highlights the importance of peer interaction in formal education, there is a gap in understanding how its functions in informal learning environments [7]. The gap remains even larger, particularly when understanding learning through collaborative engagement in engineering among multilingual and multidialectal learners.

Language serves as a vital resource in shaping peer interaction, especially in multilingual and multidialectal settings. For language-minoritized learners, leveraging their linguistic repertoires and practices can enhance collaboration, build stronger mentoring relationships, and foster leadership within learning groups [4]. In these contexts, language enables students to express their community-based knowledge, which is often overlooked in formal learning environments [5]. Building on the work of scholars examining the intersection of language and learning in STEM [2], [7], [8], [9], and attending to social exchanges in the form of peer interactions - e.g., cooperation, play, and conflict resolutions [2], we are particularly concerned with how language-minoritized learners engage with one another to make sense of the world around them and technological artifacts through their community resources.

Our work explores how peer interaction and language resources shape learning within informal multilingual and multidialectal engineering environments. The study theorizes how scholars can use the three key dimensions of engagement, mentoring, and leadership to make sense of STEMcyclist, an informal STEM initiative that fosters engineering learning through bike and biking related activities. By focusing on these dimensions, this work seeks to contribute to research on the importance of peer interaction and language resources in informal STEM education.

Conceptual Framework

Peer Interaction in Informal STEM Environments

Informal STEM learning refers to the acquisition of knowledge in science, technology, engineering, and mathematics outside the traditional classroom setting and has garnered increasing attention with advancements in technology [10]. Kalmar further emphasizes informal learning as a combination of life and learning, relying on systematic and cumulative aspects of experiential learning [11]. Phillips emphasizes the importance of informal learning environments in engineering education, noting their potential to facilitate knowledge sharing and community engagement [12]. Peer interaction in educational settings involves the exchanges and collaborative efforts among students during learning activities. These interactions can manifest in various forms, including cooperative learning that can take place in structured group work where students engage in problem-solving tasks together [13]. In such environments, students discuss concepts, share ideas, and negotiate meaning together. This collaborative process allows students to deeply understand STEM concepts as they apply them to engineering problems. Rivadeneira and Inga highlighted that peer interactions bring dynamism to the learning process by enabling the clarification of doubts and encouraging students to adopt autonomous approaches, analyze content, and articulate their understanding [14]. Such interactions facilitate the co-construction of knowledge, allowing students to learn from one another, collectively solve problems, and enhance their grasp of complex concepts. Similarly, Brundage and colleagues underscore that peer learning provides opportunities for knowledge exchange and fosters collaborative problem-solving, empowering students to tackle challenges that none could solve independently [1].

Elements of Peer Interactions

Peer interaction is characterized by engagement, mentoring, and leadership [15], [16], [17]. In this paper, we are focusing on the interplay of these three elements when learning about the design of bikes and biking in multilingual and multidialectal contexts.

Engagement

Peer interactions play a critical role in enhancing engagement among learners in informal STEM learning environments. Research indicates that collaborative learning experiences can significantly increase motivation and interest in engineering, leading to an increase in engagement. For instance, studies have shown that when students work in groups, they are more likely to participate actively, share ideas, and develop a sense of belonging in STEM [18]. This social interaction can create a supportive atmosphere where learners feel safe to explore engineering concepts and take intellectual risks [19]. Engagement is further influenced by the quality of peer interactions. High-quality interactions, characterized by constructive feedback and shared problem-solving, have been linked to improved understanding of physics concepts [1]. Engagement is contingent upon the existence and effectiveness of how students interact with one another in the learning experience.

Mentorship

Peer mentoring emerges as a significant aspect of informal STEM education, particularly in engineering education [20], [21]. The collaborative nature of peer interactions allows peers with various levels of expertise and knowledge to support each other, facilitating a reciprocal learning environment [22]. This mentorship dynamic aids in the understanding of engineering principles and also helps develop essential social competencies and self-efficacy among learners. Research by Topping highlights the positive impact of peer tutoring on academic performance, noting that both tutors and tutees benefit from the experience [23]. In informal learning environments, where traditional authority structures are often absent, peer mentoring can empower learners to take ownership of their education, thereby enhancing their engagement and commitment to learning [24], [25].

Leadership

Peer interactions within informal engineering learning environments also foster leadership competencies. When students engage in collaborative problem-solving, they often assume various roles within the group, including that of a leader [26], [27]. This experiential learning process allows students to practice and refine leadership competencies such as communication, decision-making, and conflict resolution. Moreover, leadership in these contexts is often distributed among peers, promoting a sense of shared responsibility in accomplishing the task at hand [28]. This distributed leadership model enhances group dynamics and cultivates a sense of community and collaboration, which is essential for successful learning in STEM disciplines.

Language Resources in Peer Interaction

In educational contexts where interaction and communication are central to learning –such as when students learn to design solutions to engineering problems, language plays a pivotal role in socializing learners into the knowledge and practices of engineering. Beyond basic communication, language fosters cognitive development, meaning making, and sociocultural understanding, enhancing social bonds with knowledge and practices acquired [4], [29]. This role of language is particularly crucial in connecting technical disciplines and students' backgrounds [30]. Research highlights the significance of language in engineering education, where linguistic diversity often shapes how students express and understand complex concepts. Multilingual and multidialectal learners, in particular, benefit from using their linguistic repertoires to meaningfully engage with peers, and co-construct knowledge [14], [31]. For example, Rivadeneira and Inga emphasize that peer interactions encourage students to articulate their understanding, leading to improved cognitive engagement [14], while Silvestri and colleagues underscore the importance of communicative literacies for effective participation in engineering contexts [31].

Multilingual and multidialectal students – who often engage in border crossing between the realities of their communities and those of the disciplines and the dominant society– engage in peer interactions with an understanding of how to navigate linguistically rich environments for learning between languages and cultures, facilitating new applications and community-centered understandings of engineering concepts. These peer interactions where students collaborate in engineering in multilingual and multidialectal ways are rarely free of challenges. However, research suggests that with diverse language practices and cultural understandings among students also arise opportunities to learn from different viewpoints and lived experiences, especially when students with varying language repertoires collaborate on engineering tasks. For instance, bilingual students using their home language to explain mathematical concepts engaged more deeply with the content and facilitated group understanding as opposed to generating additional linguistic and cognitive conflicts [32]. Similarly, Moschkovich argues that validating students' linguistic backgrounds enriches learning environments and promotes inclusivity among all students [33]. By recognizing and integrating diverse linguistic practices, educators can create equitable opportunities for multilingual and multidialectal learners to thrive in engineering education.

The dexterity of multilingual and multidialectal learners to make sense of the world around them through the richness of their language and experiences is what scholars refer to as translanguaging, "the deployment of a speaker's full linguistic repertoire without regard for adherence to socially and politically defined boundaries of named languages" [34]. As a critical practice for multilingual and multidialectal learners in engineering and science education students engage in translanguaging for sense-making about natural phenomena, problem solving and the design of the built environment during science and engineering activities [35][34]. In his study on multilingual sense-making, Suárez documented a pattern where emerging bilingual students used translanguaging and multimodal practices – blending Spanish, English, and gestures– to articulate their findings about electrical phenomena [36]. Importantly, his research highlights the unequal opportunities for translanguaging among students and emphasizes that gesturing, alongside linguistic resources, is a vital semiotic tool for expressing and co-constructing knowledge. These findings underscore the need to design inclusive educational spaces that value and integrate diverse linguistic and semiotic resources, allowing multilingual and multidialectal learners to fully interact with peers in the languages that facilitate their participation and thriving in engineering education.

Learning & language use: Opportunities provided by learning to design bikes and biking

Real-world activities where students engage in understanding and designing artifacts in their everyday lives have shown to be impactful for learning. Youth thrive in practical and experiential programs where they can form hypotheses about the world around them, test them, and explore how these concepts apply to real-life scenarios [35]. In such experiences, learners actively engage their hands and minds [37] by drawing on their knowledge and practices – e.g., including their understanding of how to use tools– to design, solve practical problems, and make sense of the world, which motivate and supports their participation in the learning process and make visible the relevance of disciplinary ideas in their day to day [35]. For example, bikes are artifacts in youth everyday life that provide opportunities for thinking and learning about engineering. In their day to day, some students use bicycles as a means of transportation to school. For others, bikes are a way of spending leisure time with their friends. The practice of biking and designing a bike also allows for engineering-related activities, including tinkering, redesigning, repairing, customizing, re-mixing, repurposing, building, and rebuilding. Because many students are familiar with bicycling tradition in their local context, bicycles provide opportunities for students to engage with the community outside school through bikes as design artifacts. This familiarity to the bike as an artifact lowers the barrier to entry. It makes the design process feel relevant and helps students to see themselves as engineers working on something that directly matters to them.

Several studies highlight the potential of bikes and biking as a technological design artifact and a medium for learning about engineering knowledge and practices. While Marlowe and colleagues used a bicycle as a physical object to teach the concepts of how gear ratios affect the output speeds and torque for a given input, Olsen did a study focusing on a unit about building electric bikes designed for 6th graders. The findings suggest an increase in students' interest in engineering, greater confidence in problem-solving competencies, and improved engagement with engineering practices such as design [38],[44]. Merrill, and Stitzer emphasize that such experiences of understanding, designing and building bicycles reinforces conceptual learning and fosters deeper connections between students' knowledge, competencies, and dispositions [35]. Similarly, Dietrich worked in the Magee community, where bicycles were leveraged to teach in secondary schools—a community where cycling is especially relevant to students. This cross-cultural exploration highlights the importance of a curriculum that incorporates students' experiences and community involvement, to promote socially conscious citizenship, and foster critical thinking among students [39]. In multilingual and multidialectal contexts, opportunities to learn through the practice of designing a bike and biking are not limited to the artifact itself. Drawing on the lessons learned from a study on designing learning games about public transportation [40], we can develop a vision where design artifacts afford opportunities for engineering learning and problem solving while centering the experiences and languages/dialects of communities—ensuring that all students could fully engage and present their ideas in ways that are meaningful to them [40].

Program Overview

This paper attempts to start the conversation to develop a conceptual diagram of how our work grapples with the interplay and significance of language resources and peer interactions in learning to engineering through everyday artifacts and activities, such as bikes and biking (See Figure 1). Through an asset-based approach, we center on leveraging students' unique strengths and community resources, including their lived experiences, language, knowledge, and cultural perspectives, alongside their problem-solving strategies and ways of thinking [41], [42]. As shown in Figure 1, our conceptual framework departs from three assets, which we consider as critical for learning to engineer: Bikes/biking are artifacts for learning (Asset 3), language resources and familiarity with the technology (Asset 2) relationships among students –peer interaction– (Asset 1). Through the consideration of these assets, we aim to create technical and scientific learning environments that fosters high quality experiences for multilingual and multidialectal students in STEM. For example, programs such as STEMcyclist (NSF 2314260), integrate engineering-related activities where students apply design principles to rebuild bikes, explore the biomechanics of biking, and use the bike as a lens to uncover and interact with the built environment in the students' communities. Through this two-week summer program, youth engage in science and engineering activities by drawing on their multilingual and multidialectal resources to design safe helmets, select appropriate materials for bikes and helmets, apply structural engineering and mechanical systems, engage in ergonomic design thinking, and innovative bike designs. These experiences are rooted in everyday contexts, enabling students to connect STEM concepts with their backgrounds.

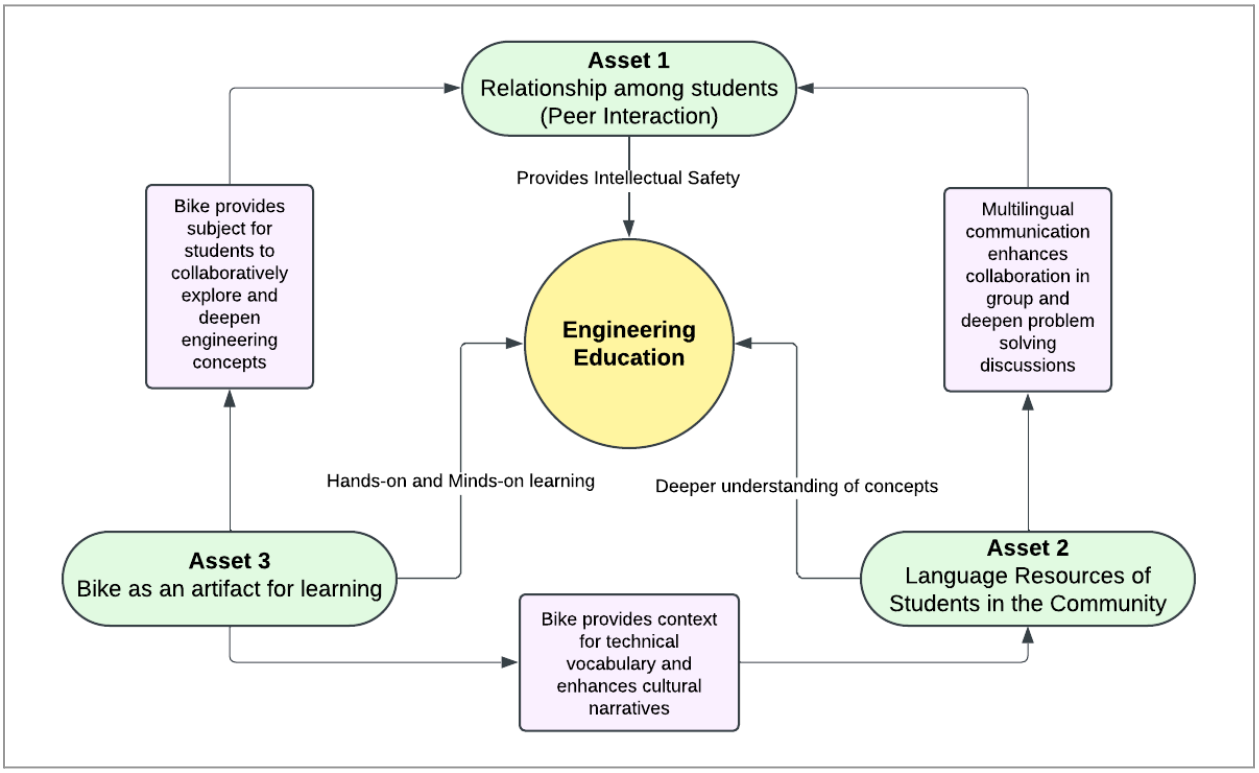

Figure 1. Initial conceptual diagram representing the connection between peer interaction and language resources in informal learning environments associated with learning through biking.

The program, which was planned to impact 96 students in grades 9 and 10 over three years, adopts a comprehensive research design. Data collection will include observations and video recordings of sessions, semi-structured interviews with students, mentors, and instructors, as well as student-generated artifacts such as designs and project plans. In STEMcyclist, students learn about and through bikes and biking in an environment where they can interact with others who share their language background and the common experience of being part of the community in Buffalo.

From our conceptual understanding, and under the assumption of an asset-based approach, engaging in engineering through bikes and biking in informal learning environments supports four interrelated learning goals: (a) applying engineering design principles and scientific practices through bike rebuilding, (b) understanding the biomechanics of bikes and biking, (c) using the bike as a medium to explore STEM phenomena in the community, and (d) supporting youth STEM identities by honoring their language resources and peer relationships as tools for learning and discovery. Rather than relying on remedial approaches, this perspective draws on Vickers's vision for embedding language and culture into how scholars and practitioners think about engineering education [43], using both task-based learning and discipline-specific language support to enhance collaborative success and learning.

Conclusion

In informal STEM learning environments, peer interaction fosters idea-sharing among students and enables the co-construction of ideas and understanding of engineering concepts. Learning with bikes—an artifact personal to students—and the process of biking—a culture cherished in the community—provides a valuable opportunity for engineering learning among multilingual/multidialectal students. These kinds of experiences of learning through artifacts highlight the centrality of language in how students communicate with peers and conceptualize STEM concepts. However, understanding how peer interactions function in informal learning environments, where students have the freedom to explore, build and experiment, remains an under-researched area, particularly for language-minoritized learners. Through this paper, we aim to explore how peer interactions and language resources influence students' sense-making of engineering activities in an asset-based program, STEMCyclist, emphasizing the three key dimensions of engagement, mentoring, and leadership.

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