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Developing Inclusive Engineering Opportunities (Fundamental Research)

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Developing Inclusive Engineering Education Opportunities

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Abstract

Historically, children with moderate to severe intellectual disabilities (ID) and extensive support needs (ESN; individuals who require ongoing, intensive assistance in many areas of life) have been largely excluded from meaningful participation in STEM instruction. A focal point of this project was to investigate the behaviors of both teachers and students during the implementation of an engineering unit. The initial data were collected as part of a federally funded research project (Jimenez & Courtade, 2021-2026) that aims to explore how teachers can effectively scaffold engineering instruction for students with ID/ESN focusing on fostering skills that promote self-regulated learning. Teacher perspectives and student outcomes are shared. The authors also present the importance of building a supportive framework for teaching engineering to students with ID/ESN, as well as ideas about what we still need to know.

Developing Inclusive Engineering Education Opportunities

Background on STEM Education and Inclusion

Historically, children with moderate to severe intellectual disabilities (ID) and extensive support needs (ESN) have been largely excluded from meaningful participation in science instruction. This exclusion has often been based on the assumption that these students cannot access or benefit from grade-aligned academic content, especially in complex fields like science, technology, engineering, and mathematics (STEM). The American Association on Intellectual and Developmental Disabilities (AAIDD) defines ID as a condition with onset during the developmental period (before 18 years of age) that involves intellectual impairments (e.g., reasoning, problem-solving) and challenges in adaptive behavior, including social skills and practical skills (AAIDD, 2021). Intellectual disability is typically classified into different levels of severity—mild, moderate, severe, and profound—based on the degree of support needed. Extensive support needs (ESN) refers to individuals who require ongoing, intensive assistance in many areas of life. These individuals may have significant challenges in performing daily living tasks, requiring substantial assistance or adaptations in educational, social, and community settings. According to the AAIDD, individuals with extensive support needs often face difficulties in mobility, communication, self-care, and decision-making, and they may need help with medical, emotional, and behavioral challenges (AAIDD, 2021). These support needs can be seen across various aspects of life, from participation in academic settings to community involvement and self-management.

STEM education is about more than just content knowledge; it also emphasizes teaching students the processes of inquiry, problem-solving, and critical thinking—skills that are fundamental to participating in and shaping the world around us (Knight et al., 2020). These processes, which include asking questions, investigating the world, and solving real-world problems, can be especially impactful for students with ID/ESN by fostering self-determination and improving quality of life (Wehmeyer, 2020). Curiosity about the world and the ability to solve problems are basic human traits, and even students with the most significant disabilities can engage in these processes if given the right support. For instance, students might explore questions like "What are the benefits of eating different colored fruits and vegetables?" or "How do plants help clean the air and why is this important?" In each case, they are not just learning facts—they are learning how to ask questions, test solutions, and make informed decisions. These skills, which are essential in STEM education, can empower students with ID/ESN to take an active role in shaping their own lives. For students with ID/ESN, proficiency in STEM subjects expands their ability to engage with the world in meaningful ways, whether through scientific inquiry, engineering practices, or using technology to solve problems (NGSS Lead States, 2013).

Gaps in Research

Researchers emphasize that providing students with ID/ESN access to high-quality, grade-aligned academic content is essential for their growth and development, as it fosters critical life skills and improves overall well-being (Turnbull et al., 2003; Wagner et al., 2006). Recent research has shown that well-designed, accessible academic instruction can significantly improve the quality of life for all individuals, including those with ID/ESN (Spooner et al., 2019; Turnbull et al., 2003; Wagner et al., 2006). Yet, despite federal laws like the Every Student Succeeds Act (ESSA, 2015) ensuring that all students have access to grade-level academic content, students with ID/ESN are still frequently denied high-quality instruction in core academic subjects like science. A common misconception is that students with ID/ESN are not capable of engaging with grade-aligned content in science and other STEM areas, or that such content is irrelevant to their lives (Agran et al., 2020; Courtade et al., 2007). In practice, when these students do receive academic instruction, it is often limited to foundational skills in subjects like early reading and basic math (Browder et al., 2020; Browder, Spooner, et al., 2020), with little to no exposure to the richness and complexity of scientific inquiry.

The Next Generation Science Standards (NGSS) emphasize the importance of scientific and engineering practices (SEP) as core components of student learning (NGSS Lead States, 2013). These practices include critical thinking, problem-solving, and the application of engineering principles, all of which are crucial for preparing students for future careers and for enhancing their ability to engage with the world around them. However, despite these broad mandates, there remains a striking lack of research on how students with ID and ESN, who may need pervasive and ongoing support in academic and daily living activities, engage with engineering practices. This gap in both research and instructional practice leaves many students with disabilities excluded from fully participating in engineering learning opportunities.

Current State of Research in STEM for Students with ID/ESN

In recent years, special education researchers have focused on developing accessible, grade-aligned instructional strategies for STEM education (Bowman et al., 2019; Browder, 2008; Cannella-Malone, 2021; Spooner et al., 2011, 2019). Of the STEM content areas, mathematics has been the most researched area for students with ID/ESN, with science and engineering studies at a significantly lower rate. In 2019, Spooner et al. conducted a literature review of mathematics studies and determined evidence-based practices for teaching mathematics. In comparison to a previous meta-analysis of mathematics studies (Browder et al., 2008), Spooner et al. noted an increased focus on grade-aligned skills. Further, the authors determined five evidence-based practices to teach mathematics to students with ID/ESN including the use of (1) systematic instruction, (2) technology-aided instruction, (3) graphic organizers, (4) manipulatives, and (5) explicit instruction. Further, in a literature review conducted by Bowman et al. (2019), the authors indicated that mathematics research has started to diversify in the skills that are being taught to students with ID/ESN (i.e., grade-aligned skills). These authors also determined promising practices that can be used to teach mathematics skills including the use of concrete representations, anchored instruction, and the use of instructional technology.

Although there has been a marked increase in research about teaching academic skills to students with ID/ESN, there are very few studies that focus on teaching science to students with ID/ESN. However, authors of a recent literature review did find a limited number of studies in which science content was being taught and gleaned that using supports, students with ID/ESN can learn science content and skills (Cannella-Malone, 2021). Further, two previous literature reviews defined evidence-based instructional strategies to teach science to students with ID/ESN. These evidence-based practices include specific supports and strategies for teaching science to students with ID/ESN, ensuring that they too can benefit from the knowledge and skills provided by STEM education. Spooner et al. (2011) found systematic instruction to be an evidence-based practice for teaching science content. More recently Knight et al. (2020) determined multiple exemplar training, task analytic instruction, and time delay to also be evidence-based instructional practices for teaching science content. Within the scope of the literature review, Knight et al. also reviewed which of the NGSS science practices are represented in studies for teaching students with ID/ ESN. Science practices were only explicitly taught in a minimal number of studies.

Similar to science, there is very little research on teaching engineering practices to students with ID/ESN. In fact, Jimenez et al. (2021) is the only research study that specifically investigates the development of engineering practices of this population of students. In their study, the investigators were interested in the impact of a universally designed engineering curriculum on the engineering habits of mind (e.g., develop and use processes to solve problems) students with ID/ESN during *Engineering is Elementary (EiE)* design challenges. The study addressed the development of *EiE* lessons by utilizing the Universal Design for Learning (UDL) Framework (CAST, 2024) to embed previously mentioned evidence-based practices across lessons (e.g., task analysis)) to support learning opportunities. Additionally, teachers embedded explicit and systematic instruction to support students' habits of mind (e.g., system of least prompts to support the investigation of properties and uses of materials during the development of a hand pollinator). The researchers determined that engineering instruction does not just develop engineering knowledge and practices, but also the development of problem-solving, self-efficacy, and self-regulated learning for students with ID/ESN.

Sukhai and Mohler (2016) assert that students with disabilities can lack exposure to the sciences, starting in elementary grades. Although researchers have defined evidence-based instructional practices that are effective for teaching mathematics and science to students with ID/ESN, there is still a question of whether educators are teaching these skills, and engineering, in their classrooms. Many students with ID/ESN are taught in self-contained classrooms by one teacher who is expected to have pedagogical knowledge of all content areas. If we expect these teachers to have knowledge of engineering, or teach integrated STEM lessons, then we must make the assumption that preparation programs are teaching special educators about STEM. As many preparation programs for teachers of students with ID/ESN focus more on functional life skills instead of academics, this may not be the case. For students that are included in general education classes, there are still barriers to participation in STEM education. Klimaitis and Mullen (2020) identified barriers such as (but not limited to): teachers and principals lacking vital knowledge and skills; lack of PD and training targeting inclusive STEM education practices; and low expectations for disabilities. So, although best practices for teaching STEM to students with ID/ESN have been identified, STEM instruction may not be taking place for students with disabilities.

Current Challenges Faced by Educators

This historical exclusion reflects broader trends in the education system, where the needs of students with ID/ESN have been overlooked in STEM research and practice. Despite advances in inclusive education and federal mandates for access to general education curricula, this population of students continue to face barriers in accessing high-quality, engaging STEM instruction. The research presented in this paper showcases advances in STEM education, specifically engineering education for students with disabilities. Due to the nature of our recent research focused on engineering design of elementary students with ID/ESN we have been able to realize the needs of both the students, but more importantly the educators serving those students. While this particular research has focused on students with ID/ESN in self-contained classrooms; much of our research findings also showcase important data to guide professional development within inclusive classrooms.

Methods

This study is part of *Project BEES (Building Engineering for students with Extensive Support needs)*, an NSF-funded research project focused on engineering education for students with multiple and significant disabilities (MSD). Our research investigated teachers' development of engineering-focused instruction, with particular attention to how they cultivate engineering behaviors and mindsets in their students.

Curriculum & Participants

The research examined five elementary special education teachers implementing the Youth Engineering Solutions (YES) curriculum in special education classrooms across two U.S. states using both qualitative and quantitative measures. Teachers implemented the Youth Engineering Solutions (YES, 2024) curriculum, which is a free, standards-aligned educational resource aimed at making high-quality engineering education accessible through hands-on, inquiry-based learning. The curriculum focuses on real-world STEM design challenges and includes scaffolded lessons where students identify problems from a read-aloud story, acquire new engineering-focused vocabulary, devise solutions, and engineer technologies that solve the problem. Specifically, participants used the Pumpkin Hand Pollinators unit which engages students in designing and building a hand pollinator to address the problem of insufficient bees for pollinating pumpkin flowers, thus impacting pumpkin production in the community. Participants were five special education teachers from public and private schools, recruited through purposeful sampling.

Professional Development and Mentoring

The curriculum was provided in its original format, with teachers modifying instruction as needed using Universal Design for Learning (UDL) strategies. Teachers attended four full-day professional development (PD) sessions (January–May 2023) to deepen their understanding of engineering concepts and pedagogy. Additionally, teachers participated in mentoring and support sessions within their own classroom during observation sessions.

Data Collection & Analysis

Data were gathered through individual interviews, observations (in person and virtual), focus groups, and self-efficacy surveys. Upon completing the engineering unit, teachers participated in virtual, semi-structured interviews via Microsoft Teams, where they reflected on their teaching experiences, instructional strategies, and any modifications made to support student learning. In addition, focus groups were conducted during three of the four professional development sessions, providing opportunities for teachers to discuss their lesson implementation, share modifications, and reflect on their overall experiences. The researchers facilitated these discussions, allowing for open-ended dialogue as well as guided questioning in later sessions. To assess changes in teachers' confidence over time, a self-efficacy survey was administered at three points throughout the study: before training, after one month of implementation, and following unit completion. Triangulation across interviews, focus groups, and survey data was used to confirm consistency and strengthen the validity of findings.

Despite the potential of engineering lessons to provide a structured approach to engineering education, little is known about how teachers support students with disabilities in developing engineering practices. Across multiple years and through observations (in-person and videos), professional development, self-efficacy surveys, focus groups, and individual interviews, we were able to identify certain instructional behaviors, some effective and others that we felt needed to be reshaped with additional professional development focused on some of the general research based instructional practices in teaching students with ID/ESN.

Initial Findings and Considerations

Teacher Perspectives

Initial Reservations and Teacher Concerns

At the start of the program, participants seemed excited and willing to participate in this new experience, however, upon completion of the engineering unit (YES, 2024), while conducting individual interviews and focus groups, each teacher opened up about and reflected on how they were initially skeptical at the beginning in both their students' abilities to engage in engineering curriculum, but also their own abilities in teaching and supporting their students in doing so (Rathmann et al., 2025). One participant stated that:

> When I first started, I had no idea, like, how I was even gonna go about teaching engineering to my students. I was like, this is not going to go over well, like I just thought I was going to be way higher thinking than what they were able to do.

A prominent theme that emerged from these data was teachers' discomfort with allowing students to experience failure and their struggle to encourage perseverance throughout the engineering design process. Teachers recognized that fostering independence was critical for students to develop their engineering identities, yet they found it challenging to refrain from intervening. One teacher described the difficulty of "sitting on your hands" and letting students take ownership of their work, explaining that "to be a good engineering teacher, you have to let the students be engineers… it's important for their identity to do things on their own." She emphasized the tension between resisting the urge to prompt students, such as suggesting adjustments, and allowing them the space to explore solutions independently.

Some teachers reflected on their tendency to step in too quickly, often rescuing students before they had a chance to persevere through challenges. One participant admitted, "I feel like maybe I came to the rescue a little bit," noting the need to give students more time or find alternative ways to guide their problem-solving. Another teacher shared how stepping back allowed her students to exceed her expectations, reflecting, "Overall, they impressed me. It made me thoughtful about the ways I try to step in instead of letting them discover."

Additionally, teachers shared their regrets in regard to challenging their students from the beginning due to their hesitation that their students wouldn't be able to do some of the more challenging activities with one teacher sharing, "I just regret not like trying things that they probably, maybe or maybe not would have done."

Along with the activities, there was skepticism on some of the soft skills involved with the habits of mind. One of the skills that teachers shared that they lacked confidence in was their students' ability and willingness to work in teams. However, they did start to see this skill progress in some of their students throughout the engineering process with one participant expressing her surprise reporting that, "This kind of feels like a surprise because I was like, they can't work in teams, but then I was like, those two could have been a team."

Another significant theme that emerged was participants' lack of confidence in their ability to teach engineering effectively. Many teachers approached the program with skepticism about their capacity to implement an engineering curriculum. One participant admitted, "I never thought that I would successfully be able to, like, implement any engineering curriculum. I was very skeptical. I was like, I want to try it, but I don't know how it's going to go." This self-doubt often extended to concerns about how they could integrate exploratory and hands-on engineering phases into their daily routines while maintaining classroom management.

Some teachers worried that engineering activities would be met with resistance or behavioral challenges from students. One teacher reflected on her initial hesitation, sharing, "I thought they would think it was going to be hard and something different and they wouldn't want to do it and there would be lots of behaviors. But really there wasn't—they all did amazing." Despite these initial concerns, participants began to see their students embrace the lessons with enthusiasm and engagement.

For some teachers, the hands-on and creative aspects of the lessons were the most intimidating to implement. One teacher, for example, expressed nervousness about leading the "imagine and plan" phase, saying, "I was actually most nervous to do the imagine and plan portion because I was like, ohh, how's this gonna go?" However, her doubts were quickly dispelled as the students exceeded her expectations: "They actually did come up with a plan and then they executed the plan, and that ended up being the easiest lesson we did. They were like the most engaged in that lesson, and that was so amazing."

Changes in Confidence and Beliefs about Teaching Engineering

Over the course of the unit, the participants were able to realize their students' capabilities as well as their own. Throughout the project participants were asked to fill out self-efficacy surveys 3 separate times; at the beginning of the first professional development (PD) before receiving training or experience on engineering instruction, at the beginning of PD 2 after implementing one month of engineering instruction, and at the beginning of PD 4 after completing the unit. The surveys measured their confidence in the UDL framework, their understanding of the 16 engineering Habits of Mind (HOM), their perceptions of the importance of these HOMs, as well as their confidence in fostering HOMs within their students. The overall mean scores for all participants increased in each area indicating an increase in their overall confidence with teaching engineering to their students. The HOM in which confidence grew the most were using prompting and scaffolding to support student goal setting in engineering activities; using differentiation to vary the difficulty level of engineering activities for students; modifying language and symbols in engineering content for accessibility, clarity, and comprehension for students; and identifying and focusing instruction on key elements in engineering activities (Jimenez & Elliott, 2024). One participant reinforced this increase in their confidence sharing, "I've always tried challenging my students, but the way you guys developed the lessons really helped me understand how to scaffold." Another participant shared a specific moment she felt a change in her confidence and abilities, stating "I was more surprised by what they were able to understand and grasp with some of the concepts and I just felt it gave me almost like a boost of energy that they can do hard things. Like, sometimes I sell them short and I'm like, 'I don't think they can do this' so it was a good experience." When another participant was asked about any change, she noticed about her own confidence with teaching engineering she explained that not only had her confidence in her ability to teach engineering increased but also how this increase in confidence with this content area had influenced her teaching in other ways

> I never thought that I would successfully be able to, like, implement any engineering curriculum. I was very skeptical. I was like, I want to try it, but I don't know how it's going to go. And I think the way everything was broken down for me, made me realize that it's a lot easier to teach. I mean, not easier. It's a lot easier to present them with opportunities to be engineers like in everyday lessons than I ever thought it would be. And so I do feel like it grew me in that way of maybe thinking of some different things that we can do for science in the future. Not always just using, you know your curriculum and things like that. Like really branching out and doing some challenging but really interesting and intriguing things.

Student Outcomes

Observations of Student Engagement and Collaboration

The engineering unit provided students with valuable opportunities to demonstrate their understanding of both content and practices in meaningful ways. Students showcased their knowledge through various actions, including identifying and using content vocabulary, interacting purposefully with materials, solving problems, and iterating on their pollinator designs based on data. During individual interviews, four participants emphasized how their students exhibited high levels of engagement throughout the unit. Teachers noted that students were actively engaged with materials, displayed appropriate behavior when faced with challenges, and remained on task during lessons. Additionally, they observed increased communication, collaboration, and enthusiasm among their students as they worked through the engineering tasks (Rathmann et al., 2025).

One of the participants reflected on her initial skepticism and the positive outcomes she observed, sharing, “I felt like they were communicating better and working as teams way more than what we did before—like normally any sort of group work just normally ended in complete disaster.” Another teacher expressed her surprise at how effectively her students collaborated, noting that they willingly took turns choosing materials for their hand pollinator designs.

Evidence of Progress in Problem-solving and Critical Thinking Skills

During an interview with one participant, she provided examples that illustrated her students' growth and understanding throughout the unit and across various lesson types. Early on, when students were given materials, they would only glance at them or minimally interact. However, by the end of the unit, the teacher observed significant progress: students were actively engaging with the materials, touching and manipulating them, exploring how they worked, and even attempting to assemble them. This hands-on interaction demonstrated clear growth in their curiosity and understanding. She further shared a specific example of how her students showed their understanding of the concepts when creating their own hand pollinators:

> When they first put the pompom and the pipe cleaner, when they actually put those two things together, I was like, oh my gosh. They’ve done it! They did it and it worked. And they had so much fun. So I was just really surprised how much they can, you know, how much engineering they really can do.

The same participant described her surprise at her students’ level of understanding during the lessons focused on testing and improving their pollinators. She hadn’t expected them to make significant changes, assuming they might stick with their initial designs since they worked the first time. However, the students surprised her by making adjustments and improvements. During testing, their understanding became clear as they transferred pollen between flowers and then used a worksheet to track their results, recognizing that more dots represented better performance of the hand pollinator materials. By the second round, some students had successfully increased the number of flowers pollinated, and a concluding math activity reinforced their progress. She noted that the students not only grasped the concept of improvement but also clearly demonstrated it through their actions and results.

One teacher reflected on how her students demonstrated growth not only as engineers but also in their personal development, highlighting noticeable improvements in independence and problem-solving skills. Another teacher shared a specific example of a student who showcased persistence and creativity during an activity focused on criteria and constraints. The student, working on her final piece of tape, faced frustration when her design wouldn't hold. Instead of giving up, she adapted by taping a piece directly to stabilize it. The teacher noted, "I didn't say not to... you technically followed the rules," recognizing this as a clear example of the student's critical thinking and resourcefulness.

Feedback from Educators

Surprises Regarding Student Understanding of Engineering Concepts

The participants frequently expressed surprise at how well their students grasped the engineering content being taught. Initially, many teachers were doubtful, believing the material might be too advanced for their students. However, during focus groups and interviews, every teacher shared examples of their students demonstrating a clear understanding of the concepts, often exceeding their expectations (Rathmann et al., 2025).

Teachers observed early signs of student understanding during the introductory "Tech in a Bag" activity, which explored engineering and technology concepts. In this lesson, students matched various technologies with their functions, such as forks and chopsticks for eating. One teacher noted her students successfully sorted the items, while another described a breakthrough moment when a student with limited vocal communication demonstrated understanding by picking up floss and mimicking its use. Another teacher shared a memorable example, recalling how a student identified a cup as technology and placed it on a corresponding card. She explained, "In my mind, that was his way of like, matching not only this is technology, but this is the word technology." These moments highlighted students' early comprehension of engineering concepts and provided teachers with encouraging insights into their students' potential (Rathmann et al., 2025).

The teachers were continually impressed by their students' grasp of engineering concepts throughout the pollination unit and beyond. Reflecting on a field trip to a local park, one teacher noted her surprise when students not only retained information about pumpkin pollination but also generalized and applied the concept to other plants in the park. Similarly, another teacher shared an example of her students referencing pollination while decorating Mother's Day cards nearly two months after the unit had ended (Rathmann et al., 2025). This same participant wrapped up her overall thoughts and surprises in her final interview stating:

> I know the initial can be kind of, "Our kids can't do that," but I mean, I have level one, level two, and level three students in my class. I have kids that are nonverbal. Every single one of them was able to participate in some way and gain something from it. So just do it, and you'll be surprised, I guess, would be what I would share to different teachers.

Teachers' Reflections on the Effectiveness of the Curriculum

Teachers reflected on the curriculum with a mix of enthusiasm and constructive feedback, noting its positive impact on teaching and student engagement. The structured scaffolding helped them challenge students while guiding them through complex ideas and tasks. However, some teachers pointed out areas needing improvement, especially for students with communication and motor challenges. One teacher mentioned the lack of content-specific communication tools, saying, "We don't have anything about pollinating and bees… Content-specific core boards and visual supports would be helpful." Others highlighted the need for visual response options and additional support for fine motor tasks to ensure all students could fully participate.

Despite these challenges, the curriculum encouraged significant student growth and engagement. Teachers shared how students independently applied their knowledge and confidently revised their designs by the final lessons. One teacher described how students excelled during the iterative testing process, noting, "By the third lesson, they had all improved… They could pick up pollen and drop it off, and they understood the concept of what worked well." These moments showed how the curriculum helped students build critical engineering skills and confidence.

The enthusiasm sparked by the lessons often extended beyond the classroom. For example, one teacher shared how a student continued testing pollinator designs independently, showing lasting curiosity and exploration. While teachers suggested adding more visual supports and content-specific tools, they all agreed that the curriculum successfully engaged students and supported their learning in meaningful and measurable ways.

Discussion

This project builds upon prior research to develop a theoretical framework that addresses the challenges faced by students with disabilities in STEM education. Previous empirical evidence has highlighted that traditional science curricular materials often fail to engage students with disabilities due to factors such as complex vocabulary, intricate concepts, and inaccessible media (Marino et al., 2010). Universal Design for Learning (UDL), however, provides a framework for creating flexible instructional environments that can meet the needs of diverse learners (Rose et al., 2005). This theoretical framework is grounded in earlier studies, such as those by Courtade et al. (2010), Jimenez et al. (2012, 2014), and Smith et al. (2013), which demonstrated the effectiveness of UDL in enhancing accessibility in science education. Most recently, Jimenez and colleagues (2021) applied UDL principles to engineering education through the *Engineering is Elementary* (*EiE*) curriculum, showing that when teachers implemented UDL alongside these established frameworks, students with ID/ESN were able to engage with and demonstrate growth in engineering practices, such as HOMs, across units. By integrating these earlier findings with UDL principles (CAST, 2024), this research extends our understanding of how UDL can support students with disabilities in STEM fields. It also draws on research indicating that focusing on UDL in standards, instruction, and assessment can improve accessibility for learners who have struggled with traditional instructional methods (Root et al., 2021; Thompson et al., 2005). This newly developed framework serves as a foundation for investigating how UDL can be systematically applied to enhance learning outcomes for students with disabilities, particularly in complex disciplines like engineering.

Implications

How Findings Contribute to Teacher Preparedness and Efficacy

Educators Reluctancy to ask "Open-ended" Questions

Throughout the engineering unit, there were a number of inquiry-based questions that required open responses from students and are meant to guide them through their thinking process. Inquiry-based questions are a critical component of engineering design and foster HOMs like creativity, critical thinking, and problem-solving. While these questions encourage students to explore possibilities, articulate their reasoning, and engage in iterative processes essential to engineering, our participants reported that they faced significant challenges and hesitations when asking these types of questions to students with ID/ESN during the engineering hand-pollinators unit. One teacher explained that she often had to limit the open-response nature of questions by providing visual choices, as her students with limited vocal communication needed additional supports to engage. Similarly, another teacher admitted feeling as though she was "talking to a wall" when attempting to elicit open-responses, often needing to guide students toward answers as silence or confusion dominated the exchanges. This difficulty sometimes led her to avoid asking inquiry-based questions altogether, fearing it might cause frustration, emotional reactions, or behavioral issues when students struggled to respond. Another teacher echoed these sentiments, identifying the language barrier as the most challenging aspect of the unit and expressing uncertainty about how best to bridge this gap. Across these reflections, it became clear that although supporting students in engaging with inquiry-based questioning is vital for helping them develop these skills, even in adapted ways, the teachers often wrestled with balancing the value of inquiry-based questioning with the need to adapt for their students' communication and engagement abilities. These findings indicate a need for additional training for educators on how to engage this population of students in this type of questioning technique.

Importance of Building a Supportive Framework for Teaching Engineering

Research highlights the many benefits of engineering education for students with ID/ESN, yet it also reveals significant gaps in teacher knowledge and skills for implementing engineering curricula in classrooms (Rathmann et al., 2025). Studies indicate that both general and special educators often feel unprepared to teach engineering concepts, particularly to students with ID/ESN (Knight et al., 2020). Due to the historical exclusion of students with disability from engineering education and related research, there is limited understanding of how to engage these students effectively and foster their engineering behaviors and mindsets. This lack of research contributes to the other challenge of preparing educators to teach engineering to students with disabilities (Grossman et al., 2009; Luna, 2018). To address these challenges our framework within this project incorporates Universal Design for Learning (UDL), which focuses on creating inclusive educational environments that address the needs of diverse learners. UDL encourages the use of multiple means of representation, expression, and engagement, enabling educators to design flexible and accessible curricula. By applying these principles, students with ID/ESN can interact with and engage in learning in ways that align with their unique strengths and preferences. This approach not only enhances their academic achievement but also fosters their well-being and sense of belonging within the school community (Rathmann et al., 2025).

Inclusive STEM Education: The Role of Universally Designed Instructional Materials

Universally designed instructional materials refers to instructional practices and materials that make learning accessible to all students without losing the big idea of the lesson itself (CAST, 2024).With students with ID/ESN this could include picture choice options for answering questions, repeated storylines to help them identify the main idea of a story and using communication boards and/or devices to allow students who may not communicate verbally the opportunity to respond and interact throughout a lesson. Throughout our project we found that some of our participants would skip questions that required critical thinking from their students for fear that their students would not be able to answer them. This example, along with other observations, lead the researchers to create materials that would be able to align with the UDL framework. This included creating answer options and communication boards in different formats to create an environment where all students could engage in the engineering lessons in meaningful ways.

What We Still Need to Know

It remains uncertain whether teachers will continue to effectively adapt and modify their engineering instruction for students using the UDL framework once external supports are faded by researchers. Additionally, it is unclear whether teachers will consistently identify and prioritize the most essential knowledge and skills from a unit, ensuring that these key concepts are adequately addressed throughout the lesson. While UDL provides a flexible structure for meeting diverse learner needs, its sustained impact on individualized instruction and curriculum focus depends on how well teachers internalize these strategies and maintain their effectiveness over time.

Closing

A promising path forward is the emphasis on providing high-quality professional development for all educators focused on STEM instruction for students with disability, including those with ID/ESN. Research highlights the significant impact of professional development opportunities that include demonstration, practice, and coaching, which help educators improve their effectiveness in teaching students with disabilities (Joyce & Showers, 2002). Well-designed professional development equips teachers with the knowledge, skills, and confidence necessary to implement evidence-based strategies in STEM education. This support is crucial not only for meeting the high standards students with disabilities deserve, but also for ensuring that students with ID/ESN receive meaningful, challenging learning opportunities. High-quality professional development has the potential to be transformative, particularly in STEM subjects such as engineering, an area where the needs of students with ID/ESN have historically been underrepresented (Kretlow & Bartholomew, 2010; McLeskey & Waldron, 2011).

While there is still much to learn, research has already demonstrated that students with ID/ESN have the capacity to engage with foundational math and science concepts when provided the right supports (Browder et al., 2012). These students are not only capable of learning basic STEM skills, but they also show potential for participating meaningfully in engineering education, a field that has traditionally been out of reach for many with ID/ESN. Addressing this gap is essential, as it holds the key not only for advancing academic inclusion but also for equipping students with critical skills that will enable them to thrive in a rapidly evolving world where engineering and technology play an ever more central role.

By focusing on inclusive, research-based practices and enhancing teacher preparation through targeted professional development, there is significant potential to enhance the learning experiences of students with ID/ESN. This effort will help bridge the gap between policy and practice in STEM education and ensure that students with ID/ESN can access the high-quality instruction they deserve. In particular, expanding participation in fields like engineering can have a profound impact on these students' quality of life, independence, and future opportunities—outcomes that are crucial for their success in an increasingly complex and technology-driven world.

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