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Finding the Fit: Secondary STEM Teachers Translating University Research into Classroom Instruction (Fundamental)

Dr. Marsha Sowell, Texas A&M University - Kingsville

Dr. Sowell is an associate professor of education. Her research interests include innovative curriculum development, AI in the classroom, brain research, and teacher leadership.

Mohammad Motaher Hossain, Texas A&M University - Kingsville

Mohammad Motaher Hossain is an Associate Professor in the Department of Mechanical & Industrial Engineering at Texas A&M University-Kingsville. His research mainly focuses on structure-property relationship in polymers, surface engineering, polymer tribology, contact mechanics, and fracture and failure analysis of polymeric materials. He received his Doctorate degree in Mechanical Engineering from Texas A&M University. Dr. Hossain is a frequent peer reviewer for a number of journals and served as a Technical Program Committee Co-Chair, and Session Chair for various technical conferences.

Dr. Hua Li, Texas A&M University - Kingsville

Dr. Hua Li, a Professor in Mechanical and Industrial Engineering at Texas A&M University-Kingsville, is interested in sustainable manufacturing, renewable energy, sustainability assessment, and engineering education. Dr. Li has served as P.I. and Co-P.I.

Prof. Kai Jin, Texas A&M University - Kingsville

Dr. Kai Jin is a Professor of Industrial Engineering and Co-PI of the MERIT project. Her research interests include Sustainable Energy, Green Manufacturing, Quality Control, and Multi Objective Decision Making and Optimization as well as Engineering Educa

Dr. Michael Preuss, Exquiri Consulting, LLC

Michael Preuss, EdD, is the Co-founder and Lead Consultant for Exquiri Consulting, LLC. His primary focus is providing assistance to grant project teams in planning and development, through external evaluation, and as publication support. Most of his work is completed for Minority-Serving Institutions and he publishes regarding findings on a regular basis.

Finding the Fit: Secondary STEM Teachers Translating University Research into Classroom Instruction (Fundamental)

Abstract

This study investigates how secondary (Grades 6-12) STEM teachers translate authentic university research experiences into classroom instruction, illuminating the decision-making processes that shape the adaptation of complex scientific and engineering work for pre-college learners. Rather than evaluating a specific intervention, this research builds foundational understanding of how teachers conceptualize, modify, and contextualize authentic research to fit the realities of secondary education.

The study is situated within a multi-year university summer research program in which middle and high school teachers collaborated with faculty and graduate students on projects such as modeling wind farm wake effects, environmental monitoring, and machine learning. These experiences serve as a lens for examining how teachers "find the fit" between research and instruction, including the pedagogical, curricular, and logistical considerations.

The following research questions guided this investigation:

1. How do secondary STEM teachers adapt and integrate university-based research projects into classroom lessons?
2. What factors influence teachers' decisions about which elements of the research experience to include in curriculum modules?
3. What challenges do teachers encounter in translating university-based research into the constraints of the secondary classroom?

Grounded in constructivist and experiential learning theory, this qualitative study employs a constant comparative method to analyze interviews, classroom artifacts, and lesson plans from participating teachers. The analysis focuses on how educators negotiate authenticity, curriculum standards, and instructional feasibility while designing lessons inspired by research experiences.

Findings suggest that teachers engage in a dynamic process of pedagogical reconstruction, selectively reframing research procedures, data sources, and analytical techniques to align with content demands, students' developmental levels, and instructional timeframes. Teachers commonly substituted accessible datasets for original research data, modified tools and technologies to fit classroom availability, and extended or reframed concepts beyond the original research scope to increase relevance and engagement.

Introduction

Authentic research experiences for K–12 teachers have emerged as a promising strategy for strengthening precollege STEM and engineering education. Through initiatives such as university-based summer research programs and Research Experiences for Teachers (RETs), secondary educators participate directly in scientific and engineering research with the intent of deepening disciplinary knowledge, strengthening engagement with authentic practices, and enhancing classroom instruction. Prior research has documented benefits of these experiences, including increased teacher confidence, shifts toward inquiry-oriented pedagogy, and greater emphasis on real-world problem solving [1] [2] [3]. However, while the value of teacher research participation is well established, considerably less is known about what occurs when teachers return to their classrooms and attempt to transform complex, university-based research into instruction that is meaningful, feasible, and aligned with secondary education contexts.

Translating authentic research into classroom curriculum is not a simple act of replication. University research is often open-ended, technically complex, and unconstrained by pacing guides, standardized assessments, or mandated standards. In contrast, secondary teachers must design instruction within tightly bounded systems that include state standards, accountability measures, limited instructional time, and classrooms characterized by wide variability in student readiness, motivation, and support needs. These competing demands require teachers to make intentional decisions about what aspects of the research to preserve, what to simplify, and what to omit altogether. As a result, teachers function not only as instructional implementers, but as curriculum designers who actively mediate between disciplinary authenticity and classroom realities.

Within precollege engineering and STEM education research, scholars have increasingly called for greater attention to how teachers "find the fit" between authentic disciplinary practices and secondary instruction. While studies have examined teacher learning during research experiences, fewer investigations have focused on the curricular translation process itself: how teachers conceptualize research-informed lessons, how they adapt content and pedagogy for students, and how logistical constraints shape instructional design. Understanding this translation process is critical for improving professional learning experiences and ensuring that investments in teacher research programs result in meaningful classroom impact.

The purpose of this study is to investigate how secondary (Grades 6–12) STEM teachers translate authentic university research experiences into classroom instruction. Specifically, this research illuminates the decision-making processes that shape how teachers adapt complex scientific and engineering work for precollege learners. By examining both teacher reflections and lesson artifacts, this study builds foundational understanding of how educators conceptualize, modify, and contextualize authentic research to fit the realities of secondary education.

Guided by this purpose, the study addresses the following research questions:

1. How do secondary STEM teachers adapt and integrate university-based research projects into classroom lessons?
2. What factors influence teachers' decisions about which elements of the research experience to include in curriculum modules?
3. What challenges do teachers encounter in translating university-based research into the constraints of the secondary classroom?

To address these questions, the study adopts a curriculum development lens that foregrounds three interconnected dimensions of instructional design: content, pedagogy, and logistics. Content decisions involve alignment to standards and assessments and determine how disciplinary knowledge and practices are framed for students. Pedagogical decisions shape how students engage with the research through instructional strategies, scaffolding, and opportunities for sense-making. Logistical considerations, including time, pacing, testing schedules, and student variability, influence what is feasible to implement in real classrooms. These dimensions serve both as an analytic framework and as the organizing structure for the findings.

The significance of this study lies in its contribution to foundational knowledge in precollege engineering education. By articulating how teachers translate authentic research experiences into standards-aligned classroom instruction, this work advances understanding of teachers' adaptive expertise and professional judgment. The findings offer insight into how educators preserve the core ideas and practices of authentic research while reshaping them to support student learning. Additionally, this study provides implications for the design of professional learning experiences that intentionally cultivate the skills, dispositions, and supports teachers need to effectively translate authentic STEM and engineering contexts into secondary education.

Review of literature

As Hoover [4, p. 8] recognizes, the term "curriculum" is defined in many different ways, but each definition should include "three important components: (1) the intended outcomes, (2) what is taught, and (3) the manner of implementation". While acknowledging the caveats of each of these elements, for the purpose of this study we consider that the intended outcomes of curriculum, or a lesson, are tied closely to both what is taught and the manner of implementation. In this study, we define what is taught as the content of the lesson and the manner of implementation as the pedagogy and logistical components of the lesson. These elements serve as the analytic categories used to examine how teachers translated their research experiences into classroom lesson plans.

Further complicating discussions of curriculum is the idea that teachers address four types of content within the curriculum: the explicit curriculum, the extracurricular curriculum, the implicit curriculum, and the null curriculum [5]. Because the explicit curriculum is the only curriculum that is intentionally designed for the academic classroom, it is the only content we address in this study.

The National Institute for Excellence in Teaching [6, p. 1] recognized a "high-quality" curriculum as "one that is aligned to rigorous state standards". For over 30 years, the United States has sought to establish national educational standards to outline what students were required to know and do in mathematics and English Language Arts (ELA). These national standards are known as the "Common Core." Eight states currently elect not to use these standards, but have developed locally controlled, state standards [5]. Texas opted out of the Common Core and implemented state standards, the Texas Essential Knowledge and Skills (TEKS). The State Board of Education adopts these standards that "outline what students are to learn in each course or grade", not just in mathematics and English Language Arts. The use of the TEKS in Texas classrooms is non-negotiable [7]. Whether Common Core or state standards, student success in learning the knowledge and skills associated with each course and grade's standards are expected to be assessed [5]. In meeting the assessment standard, Texas requires students to take the State of Texas Assessments of Academic Readiness (STAAR). STAAR is required in reading language arts and math each year third through eighth grade, science in fifth and eighth grades, and social studies in eighth grade. Similarly, STAAR end-of-course exams are required for Algebra I, English I, English II, Biology, and U.S. History [8].

Because the Common Core only focuses on mathematics and ELA, collaborative efforts were made to create similar national standards in other content areas. For example, The National Research Council, the National Science Teachers Association, and the American Association for the Advancement of Science collaborated with 26 states to develop the Next Generation Science Standards (NGSS) [9]. Furthermore, secondary courses with additional credits must also follow the standards and assessment requirements for those credits. For example, high school Advanced Placement (AP) courses must incorporate AP disciplinary practices and learning objectives in their curriculum [10].

These standards and assessments shape not only what teachers must teach, but also how teachers prioritize and frame lesson objectives, making them a critical context for analyzing teacher-created curriculum artifacts.

One of the key foundations of pedagogy is the understanding of how students learn. Constructivism posits that knowledge is actively built by learners. Experiential learning theories are a form of constructivism that states this active learning process requires concrete experiences and reflection upon the experiences.

Foundational work in constructivism is associated with cognitive constructivist Piaget [11] and social constructivist Vygotsky [12]. Piaget's theory claims individuals construct knowledge through the interaction of experiences and prior knowledge. According to Piaget, learners' schema either assimilates to accept new experiences into existing structures or adapts to create new structures into which the new experiences fit. As schema assimilates and adapts, it must maintain equilibrium so that no conflict exists between new and existing knowledge. In this way, as a cognitive constructivist, Piaget asserts that learning comes from thinking about the experiences and how they relate to personal prior knowledge.

As a social constructivist, Vygotsky [12] asserted that knowledge is built through experiences that are influenced by culture, human interactions, and language. He argued that without other's input, an individual is limited in knowledge based only on their own experiences. As such, Vygotsky's Zone of Proximal Development (ZPD) explains that there is a difference between what an individual knows and can problem-solve alone versus what the same individual can accomplish with support from a more-knowledgeable other (MKO) such as a teacher or more capable peers. This difference is the ZPD and the area in which a teacher acts as the MKO to guide students' understanding and thus learning.

Kolb [13] took constructivism further in his creation of the experiential learning theory (ELT). Kolb postulates that to construct knowledge, an individual must experience and reflect on the experience. His theory includes four key stages: 1) concrete experience in which learners engage with new concepts, 2) reflective observation in which learners consider and reflect on the engaging experience, 3) abstract conceptualization in which learners make sense of the reflections by adjusting their thinking, and 4) active experimentation in which learners apply their new thinking and thus create a new experience and restart the cycle of learning. Critics claim Kolb's theory ignores the social and cultural influences on reflective practices and thus the learning process. However, the framework of the theory does not regulate reflection to an internal process nor a specified method and can be adapted to reflect context of the learning [14].

Taken holistically, these learning theories guide curriculum development to include opportunities for learners to experience new learning through engaging activities, reflect on how these experiences fit into their existing schema and adjust schema as needed, and apply the new knowledge in novel situations. These steps are impacted by social and cultural influences that must be accounted for in the learning process. It is through best-practices and the use of high-quality materials that teachers implement these opportunities for learners. These theories are frequently cited in STEM and engineering education research to justify hands-on, iterative, and collaborative learning environments.

High-quality instructional materials (HQIM) are aligned to content standards and evidence-based best-practices, and include support for all learners, teacher- and student-facing lesson-level material, and frequent assessment of student learning [15]. The National Institute for Excellence in Teaching [6] add that HQIM engage students in deeper learning, create focused direction in lessons, and make connections across grade levels. While HQIM provide structured supports, teachers often adapt or extend these materials to reflect their instructional goals, classroom context, and students' needs.

Evidence-based best-practices are teaching practices that have been proven effective for student learning. Some best-practices include direct instruction in which the teacher provides information including learning objectives and clear instructions, active learning in which students engage in learning through interaction with material and time to process learning alone or with others, inquiry-based learning in which students investigate to answer open-ended questions, and project-based learning in which students solve real world challenges and problems [5]. Hammond [16] clarifies that best-practices include strategies that involve students' active engagement with the curriculum, challenge students, and link to students' everyday lives.

In addition to content and pedagogical considerations, teachers must consider logistical components of their classrooms when implementing any curriculum. One of the most challenging logistical aspects of teaching is balancing time and pacing. Historically, some districts have used pacing guides as a tool for punitive oversight, with research showing that teachers could face professional sanctions or poor performance evaluations for deviating from these rigid schedules. However, legislative shifts in 2023, such as the passage of Texas HB 1605, have begun to provide critical protections in these situations. Under this legislation school districts are now explicitly prohibited from penalizing teachers for adjusting the pacing of recommended materials if the teacher determines their students need additional time to master a concept [17]. Despite the relief from punitive action, educators still strive to prepare students for success by covering all the essential content required for end-of-year standardized assessments but many "confront the inescapable reality that they simply don't have enough time to cover all the material adequately" [18].

Teachers are now expected to take an active role in the creation and adaptation of curriculum in response to student needs and classroom realities [19]. Curriculum development takes time, implementation, and adjustments. "Curriculum developers cannot anticipate or address all of the challenges that will arise once teachers begin using the resources with their students" [19, p. 3]. Addressing the diverse learning needs within a classroom is recognized as one of the top challenges facing teachers [20]. A 2024 Pew Survey found that teachers report students continue to struggle both academically and with behavior, with over half of teachers reporting that addressing behavior issues is a daily challenge in the classroom. Furthermore, 47% of teachers report that students show little to no interest in learning [21]. Wilson [22] explains that the changes in students and the differentiation that is required to address these changes are adaptive challenges. He goes on to explain:

> "Adaptive challenges require changes in values, beliefs, roles, relationships and approaches to work. The best solutions come from those involved in the work rather than from experts or those with authoritative leadership roles. Solutions may require experiments and new discoveries. They can take a long time to implement and cannot be implemented by edict" [22, para. 6].

Each class hosts a different set of students and lessons must be adjusted to meet the needs of those students, making differentiation by the teacher an ongoing process. These logistical constraints shape how teachers enact curriculum in practice and are therefore essential to understanding the instructional decisions reflected in teacher-designed lesson plans.

Taken together, the literature highlights curriculum as a multifaceted construct shaped by content standards, pedagogical theories, and logistical realities of classroom practice. While standards define what must be taught, learning theories inform how instruction is designed, and classroom constraints influence how lessons are enacted in real contexts. Teachers operate at the intersection of these forces, exercising professional judgment as they translate external experiences and knowledge into instructional plans. This study builds on this body of literature by examining how teachers incorporate research experiences into lesson planning decisions, with particular attention to how content, pedagogy, and logistical considerations are reflected in teacher-created curriculum artifacts.

Methodology

Grounded in constructivist and experiential learning theory, this qualitative case study [23] employs a constant comparative method [24] to analyze interviews, classroom artifacts, and lesson plans from participating teachers. The study examines how secondary STEM teachers translate authentic university research experiences into classroom instruction, focusing on how educators negotiate authenticity, curriculum standards, and instructional feasibility in designing lessons inspired by their research experiences.

The study is situated within a three-year university summer research program supported by the National Science Foundation (Award No. 2206864) in which middle and high school teachers collaborated with faculty and graduate students on projects such as modeling wind farm wake effects, the best placement of solar panels, and machine learning. These experiences serve as a lens for examining how teachers "find the fit" between research and instruction, including the pedagogical, curricular, and logistical considerations that guide adaptation.

Lesson documents were collected across the three-year program. Interviews with nine program participants were conducted in fall 2025. While all participants were invited to be interviewed, nine self-selected to participate. Interview participant characteristics are provided in Table 1.

Table 1.
Characteristics of Teacher Interview Participants

Pseudonym	Grade Taught	Subject Taught	Summer Program Years Attended
Ms. Bennett	6th-8th	Math	2023
Mr. Brooks	9th – 12th	Science	2023, 2024
Ms. Caldwell	9th – 11th	Math	2024, 2025
Ms. Ellison	11th	Science	2024
Ms. Hastings	9th-12th	Science	2024
Ms. Montoya	6th	Math	2023
Ms. Rios	8th	Math	2025
Ms. Salazar	9th – 12th	Math	2024, 2025
Ms. Whitmore	10th-12th	Math	2025

Note: The participants are presented in alphabetical order by pseudonym to maintain neutrality and avoid implying any hierarchy related to grade level, subject area, or program participation.

Data were coded iteratively, with emerging themes compared across participants and documents to identify patterns in how teachers translated research into instruction. Data triangulation across interviews, lesson plans, and program artifacts supported the trustworthiness of the findings.

Research findings
Analysis of the collected data illuminated how teachers in this study conceptualize, modify, and contextualize authentic research to fit the realities of secondary education. Using a curriculum development lens, these findings are presented within the three themes of curriculum development: content, pedagogy, and logistics.

Content alignment. All of the teachers interviewed expressed that one of their primary concerns in translating the university research to their classroom was the alignment of the lesson to content standards. As Ms. Montoya explained, "I'm expected to teach the sixth-grade standards."

All nine teachers interviewed recognized that the Texas curriculum standards, the TEKS, were a non-negotiable baseline for lesson development. Ms. Bennett stated this best:

> When I was getting ready to do that curriculum, I obviously had to look at my TEKS, I had to see kind of what aligned best with what we were doing over the summer and the TEKS that I was going to have to teach.

National frameworks were selectively layered on top of state accountability demands in specific courses. Mr. Brooks noted that he aligned his lessons for his advanced placement (AP) class to the AP College Board standards, and Ms. Ellison noted that she aligned her physics lesson to the Next Generation Science Standards (NGSS). The lesson plan documents revealed that all the teachers in the program were successful in making these standards alignments as well.

The teachers interviewed were already familiar with their content, so this alignment process confirmed the exact standard that they knew aligned to the content. Ms. Whitmore explained, "Teaching over the years, we know the concept – we definitely relate to all of them [the content topics], and so we go and look for the TEKS number." Ms. Caldwell even mentioned that she selected her research topic because it was "crucial" that the research was the best fit for her Algebra I and II content.

The science teachers vocalized content congruency with the research projects, making alignment to standards clear. Ms. Ellison explained, "I used the windmills as my backdrop for teaching about energy and electricity.… We tackled all sorts of curriculum components with relationships to the windmills." She went on to add that even the high school teachers simplified the university-level research noting "the detail for the students was not there, the overview of what we did was there." Mr. Brooks did note, however, that one of his university-based projects correlated to the standards for environmental systems better than the physics class he taught. He utilized those standards for his lesson and "donated it to the environmental systems teacher."

The math teachers vocalized content incongruency with the research projects, making alignment to standards more difficult. Ms. Caldwell explained "we do math and not science, so it's a little bit harder." As such, many math teachers opted to teach research and data analysis skills within their given standards while using the research content as the context and engagement element of the lesson. Ms. Montoya explained that while she could meet her math standards by having students use the data to calculate mean and median and create a dot plot, she really saw no content value in wind speed predictions. She did, however, feel that the research was important and thus included a minilesson about wind speed and how the data to be analyzed was collected. "That way they know that it's not just numbers that I'm just making up." Ms. Whitmore added that the data collected from the projects could be analyzed and "adjusted for any grade level, middle school, high school, precalculus" as students "took the measurements of the solar panels and the irradiance with the Fluke meter, and then they were able to answer questions about predictions or hypothesis."

Standardized testing in the content area also influenced where research-based lessons could best be implemented, with non-tested courses functioning as more innovated spaces. Ms. Rios explained that she was focusing more of her lessons on her non-tested design class because "it won't interfere with our actual pacing guide of the math course because it is outside of that course." Ms. Ellison agreed, saying "I have a lot of latitude with physics; like I said, I'm not a STAAR-tested area." Mr. Brooks pointed out that although the lessons follow the content standards, adhering to these standards was more than just a requirement or a means to pass a test. He explained:

> "In order to be successful on the test, and I don't want to say that I just teach to the test, we're teaching certain things in the standards. And for my students to be successful, they need to know these things. I guess those were some of the main things that I had to look at in order to create the lesson – how much time was it going to be, what I want the students to learn, what I want them to take from it, and how will it aid them in understanding the concepts that we're already teaching in the classroom?"

While the teachers interviewed were concerned about meeting the standards of their specific courses, they also expressed a desire to teach content-adjacent skills and lessons. Ms. Salazar noted "I like to show the students the need for math knowledge and show them opportunities. An engineer is going to use a lot of math. You can do that even if you're not great at math. You can still pursue this career!"

Several teachers mentioned that through the university-based research projects they learned, and now stress in their classrooms, better ways to think and operate as scientists. In the high school, Mr. Brooks noted he now puts an emphasis on “What did you do during your research to eliminate bias? How are you presenting the data in a meaningful, kind of structured way?” Ms. Salazar hoped her students learned that the scientific method is more complex than what was taught in elementary school, “it’s a lot more in depth and a lot more things you have to navigate through and problem solve through, which is really great for the kids!” In the middle school, Ms. Bennett now emphasizes that “it’s very important to collect very good data. You need good data so that your results are accurate.”

Several teachers also mentioned using the research-based classroom lessons gave them the opportunity to teach students a growth mindset. Ms. Ellison stressed that “if the project doesn’t go the way it’s supposed to go, it’s okay. You just gotta sit back, look at things, analyze it, and see why did it go wrong?... that’s just as important as getting it right.” Mr. Brooks explained, “I don’t think I really emphasized the grade too much before, but definitely more now is the learning…I’m really more concerned with the process. What did you learn? What did you experience during the whole process?”

Many of the teachers indicated that part of the benefit of the research they did at the university was learning how to use free technology resources in research and to teach their students how to use those resources. Ms. Hamilton explained, “You can do computer-based theoretical stuff. Kids know computers, but they don’t know how to use computers for educational settings. It is strictly entertainment value. It’s just neat seeing the kids, like use computers for real, for a purpose.” These teachers mentioned including instruction and use of anemometers, voltmeters, a Fluke meter, Microsoft Excel, Scribe, Google Colab, Google Sheets, and a Desmos calculator in their lessons.

While content alignment was a primary concern for teachers, it became clear that aligning university-based research to required standards was not sufficient on its own. Once teachers identified how the research fit within their content expectations, they were then faced with decisions about how to design instruction so students could meaningfully engage with that content. The complexity of authentic research, differences in students’ background knowledge, and disciplinary constraints required teachers to reconsider instructional clarity, scaffolding, and classroom structures. As a result, content decisions often served as the starting point for broader pedagogical considerations, which are explored in the following section.

Pedagogical Best Practices. While the teachers participating in this study depended on their teaching experience in lesson planning, their experience in the university-based research summer program also prompted them to remember the purposes of the teaching strategies they depend upon. Their role-reversal to becoming the learner rather than the teacher deepened their understanding of the value of best practices.

Participation as a learner in the university program reinforced the need for clarity and structure in lesson planning. The teachers’ desire for clearly stated objectives and instructional directions encouraged them to seek their own models for curriculum and lesson plan frameworks. Both Ms.

Bennett and Ms. Caldwell noted that they reviewed their district's curriculum to gain a deeper understanding of how the curriculum was framed and organized. Ms. Bennett and Mr. Brooks also noted that they reviewed similar plans on the TeachEngineering website for models of lesson plan formatting. Ms. Bennett also explored Lead4Ward for instructional strategies to engage her students.

This desire for clarity of expectations in their own learning prompted the teachers to recognize the need for clarity in the objectives and expectations for students in their lesson development. Ms. Bennett reflected, "Becoming a student again makes me realize that you have to explain. You have to have a clear explanation of the expectations of the students." Ms. Whitmore added, "Giving them [students] an objective they know the final outcome will help them go through the process a little easier, like they know what their final picture should look like, maybe model it beforehand, show them what it looks like."

Especially with the complexity of the university-based research projects, the teachers recognized the need to build student's background knowledge in the context of the research and make the lessons link to students' prior knowledge and skills. Ms. Rios noted the students are "not all coming in with the same background knowledge as you, you have to slow it down, bring it down a level. We have to build that foundational before we get to the upper level that we need." Recognizing the need to ensure students could understand the lessons, Ms. Bennett found herself asking, "how could I merge those things that we did over the summer with what the kids knew, what the kids were going to need to know for my classroom? You know, how could I make it user-friendly for them?"

The university-research program reminded the teachers of the importance of making sure they were utilizing real-world examples in lessons and showing their students the applications of the skills in multiple ways. The teachers used local relevance as cognitive anchors in their lessons. Ms. Ellison's efforts to make STEM more exciting through a connection to local windfarms was rewarded when her students recognized and made the connections. She said, "When they [the students] actually got the meter to read, they were ecstatic because it actually worked. It just really showed them this is where your electricity comes from if it's wind generated and they're like, 'oh, this is real.'" Ms. Rios combined hands-on learning and real-world applications in her lesson, by having students redo the experiment she completed in the summer program, but with the students as the experiment participants, researching the best classroom lighting for their learning. She explained her students would take assessments in artificial lighting, daylight alone, and then a mix of both to see how the lighting impacted them. Next, they would use light measurers to measure the daylight in the classroom in real-time. Ms. Rios explained her focus was on having students "see how is this impacting them personally. Using this science and this mathematics, they can pull crucial information to advocate for who they are, what helps them in their learning later on, and I think that is just the best."

The real-world contexts increased student motivation as well. Ms. Whitmore observed that students 'loved the real-world problems, the sun, the angle, that it has practical applications. They could even plug in a charger to those solar panels, charge phones, iPads, the USB charge, so they were very interested." The teachers reignited a love of learning through participating in real-world research and recognized the value in sharing this experience with their students.

While hands-on experiential learning and real-world applications have long been recognized as good instructional practices, the teachers interviewed for this study learned that teaching this way was rewarding for them as well. Ms. Whitmore said, "I definitely enjoyed it more than teaching my lesson about angles" to which Ms. Salazar added, "I would agree it's more enjoyable. Just seeing them learn in a different way, discovering something versus us giving them information exactly, definitely for all of us was a good experience."

Because research, like lesson plans, rarely follow the anticipated plan, becoming a researcher helped the teachers embrace pedagogical risk-taking: letting go of perfection, accepting ambiguity, and de-emphasizing traditional success measures. Ms. Rios asserted that the experience of writing and implementing the curriculum helped her "understand that it's not going to be perfect and it's okay. It's fine. We're going to modify it and it's going to get better." Ms. Bennett exclaimed, "Lessons never go as planned! I wish, right? But we did it! It was a lot, I planned for a lot, and I didn't have time to do everything. So I had to kind of tweak mine."

Ms. Caldwell felt acting as a learner helped her recognize issues in her teaching as she struggled to understand complex university-based research. She said, "Sometimes I could be saying stuff and I think it's so simple, and it make sense to the kids, but I have to step back. It makes sense to me but it may not make sense to them."

Taken together, these reflections suggest that participation in the university-based research experience fostered reflective practice as an explicit instructional outcome for teachers. Engaging in complex, open-ended research as learners prompted teachers to critically examine their own instructional assumptions, particularly around clarity, pacing, and student support. Experiencing uncertainty, productive struggle, and revision firsthand reframed how teachers designed their classroom lessons, leading them to prioritize scaffolding, iterative feedback, and flexibility in implementation. This shift positioned empathy as a pedagogical design insight, influencing not only how content was presented but how time, resources, and classroom structures were allocated—an insight that directly informed the logistical decisions described in the following section.

Logistical considerations. A lesson is only valuable if it can be realistically implemented in the classroom. As such, there are logistical considerations which shape the content and pedagogy that can be included in the classroom. The teachers in this study recognized and considered these logistics in their planning.

A universal reality of secondary schools is the limited time teachers have with students, and each teacher in this study identified the curriculum timeline as a major influence on their curriculum development. Many schools have a set curriculum guide or scope and sequence that teachers are not able to deviate from. Ms. Caldwell explained, "We have rules. I need to finish what I'm doing first and then we're able to tie in what we wanted to do. When we are done with STAAR testing, then I can spend May doing our project." Within these rules, Ms. Rios noted that her biggest challenge to implementing the authentic research into her math classroom was "finding the appropriate time to put it in, and make sure the students are getting time to think about it."

The university-based research experience was impactful enough on the teacher participants to warrant their buy-in in the value of introducing the projects in their classroom. The timelines, however, made this difficult so the teachers adapted the projects to fit the timeline. Ms. Montoya shortened the research aspect of the lesson by having students use data that was already collected rather than collecting the data on their own. She lamented, “It would be cool to actually have them collect the data on their own, but again, time is limited and I just don’t know how I’d do that.” Similarly, Ms. Whitmore and Ms. Salazar noted that they had to adjust their university project from the six-weeks of 12-hour days to three- or four-days of 50-minute class periods. As such, their students were still able to collect data but took fewer measurements to include in their analysis.

Aside from the traditional constraints of a school timeline, unexpected interruptions also impacted the lesson implementation, requiring further lesson adaptations. Ms. Ellison lamented, “It seems like there were so many school factors, like, we had to stop for testing for STAAR, we had a volleyball game, a track meet and half the kids were gone, or the band was gone to contests.” Bad weather delayed the data collection from solar panels, and thus delayed Ms. Hastings’, Ms. Salazar’s and Ms. Whitmore’s lessons.

The teachers felt overwhelmed by the complexity and specificity required of unfamiliar university-based research and thus recognized that adapting the research to fit secondary education required simplifying it. To make the research more understandable to her students, Ms. Whitmore explained she made the terminology more relatable: “In our experiments we talked about azimuth angles and we wanted to make it more relatable to them. So we talked about seasons and the placement of the sun instead of azimuth angles.” Ms. Montoya opted only to talk about her research in simple terms as well “because they’re sixth grade and I don’t want to lose them.” With concepts Ms. Caldwell found difficult to grasp, she realized were not key to her students’ learning goals. She explained:

> “The machine learning part of it in general was hard for us to grasp, so it’s kind of like, how am I going to take it back and make sure my students understand that? So that’s when we decided we’re not going to make them code. The code was provided to us and we can just show them pieces of the code, this is how you use it, and go from there.”

In her high school class, Ms. Hastings tried to replicate the full project data and found her students struggling to use the large amounts of data. She summarized, “This was just overwhelming…. My students – it is over their head.” Ms. Hastings then adapted the lesson to include fewer sets of data.

Like a discrete timeline in every school, every classroom has students with varying need. The teachers recognized that lesson implementation and time constraints are often impacted by these student needs. Both Ms. Whitmore and Ms. Montoya explained that their students were below grade level, so these lessons had to be shortened to allow for reteaching of required lessons. Ms. Caldwell said she was still deciding how to adjust her lesson to help students with behavior issues, modifications, and individual education plans be successful. High achieving students encouraged the teachers to adjust their lessons as well. As Ms. Montoya was considering scaling back her project for her struggling students, she was also mulling over the idea of having her advanced students use websites to collect their own weather data for analysis and making it a competition to see who could best use the data to predict the weather.

Taken together, these findings show that translating authentic university-based research into secondary classrooms is an iterative process shaped by content requirements, pedagogical design, and logistical constraints. Teachers began with non-negotiable standards, designed instruction to make complex research accessible to students, and adapted those plans to fit the realities of time, testing, and student needs. Rather than diminishing the research, teachers exercised professional judgment to simplify, scaffold, and restructure experiences in ways that preserved core ideas while making classroom implementation feasible. This highlights the central role of teacher expertise in mediating between authentic research and secondary practice.

Discussion

This research builds foundational understanding of how secondary STEM teachers conceptualize, modify, and contextualize authentic university research to fit the realities of secondary education. In the creation of lesson modules related to the research experiences, teachers engage in deliberate acts of translation that reflect both professional judgment and contextual constraints. The findings illuminate translation not as a loss of authenticity, but as a form of pedagogical expertise.

Interpretation of findings. Findings suggest that teachers engage in a dynamic process of pedagogical reconstruction, selectively reframing research procedures, data sources, and analytical techniques to align with content demands, students' developmental levels, and instructional timeframes. Teachers commonly substituted accessible datasets for original research data, modified tools and technologies to fit classroom availability, and extended or reframed concepts beyond the original research scope to increase relevance and engagement.

These adaptations reflect professional sensemaking, as teachers negotiate the tension between maintaining the rigor of authentic STEM experiences and meeting the pragmatic demands of secondary instruction. Rather than treating university research as a fixed artifact, teachers approached it as a flexible resource, reshaped through instructional goals, student needs, and accountability pressures. This process aligns with conceptions of adaptive expertise, in which educators apply disciplinary understanding creatively within constrained environments.

Addressing the research questions

RQ1: How do secondary STEM teachers adapt and integrate university-based research projects into classroom lessons? Teachers relied heavily on state standards as an anchoring structure to maintain curricular integrity. This reliance often shifted the focus from replicating research content to emphasizing transferable skills such as data analysis, modeling, measurement, and interpretation. When the content of university-based research did not align directly with secondary standards, teachers repurposed the research as a real-world context for skill application. As one teacher noted, the data were "not just random numbers for math, but come from somewhere."

Using authentic research contexts helped students perceive the relevance of abstract skills, which teachers reported increased engagement and motivation for deeper learning. Beyond standards-aligned skills, teachers also identified value in outcomes not explicitly assessed, including persistence, problem-solving, and growth mindset. These findings suggest that research integration serves both academic and dispositional goals, even when content alignment is imperfect.

RQ2: What factors influence teachers' decisions about which elements of the research experience to include in curriculum modules? Teachers' decisions were shaped by multiple, interrelated factors, including age-appropriateness, instructional time, alignment to content standards, and accountability pressures such as standardized testing. Teachers weighed whether research elements functioned best as core content or contextual framing and considered how these choices supported instructional goals. Calendar constraints, including pacing guides and interruptions to instruction, further influenced how much of the research experience could realistically be incorporated.

RQ3: What challenges do teachers encounter in translating university-based research into the constraints of the secondary classroom? Challenges closely mirrored the factors influencing instructional decisions. Content fit, developmental appropriateness, and time constraints were consistently identified as barriers, compounded by variability in students' background knowledge. Importantly, these challenges did not function as roadblocks. Teachers described reflective cycles of implementation, evaluation, and revision that allowed them to adapt lessons in response to observed student needs. Translation emerged as an iterative process, shaped by both constraint and creativity.

Implications and recommendations

The findings suggest several implications for pre-college engineering education and research–practice partnerships. First, collaborations between higher education institutions and secondary schools should intentionally account for the structural constraints of secondary education, including standards, schedules, and assessment demands. Developing shared understanding can support more effective and sustainable research-to-classroom translation.

Second, collaborative efforts should aim to align research experiences with secondary content where possible. Physics-based projects, in particular, demonstrated stronger alignment, suggesting disciplinary fit plays a role in successful translation. When alignment is limited, partnerships should explicitly frame research as a contextual vehicle for skill development rather than content mastery.

Finally, collaborators should jointly define the objectives of research-based instructional modules. This includes clarifying whether authenticity resides primarily in the research topic itself or in the practices it affords, such as data collection, analysis, and evidence-based reasoning. Explicitly addressing this distinction can help educators design lessons that preserve meaningful aspects of authentic STEM engagement while remaining instructionally viable.

This study is subject to several limitations. The sample consisted of participants from a single university-sponsored research program, which may limit the generalizability of findings to other contexts or teacher populations. Data relied on self-reported interviews and submitted lesson artifacts, which may reflect intended rather than enacted classroom practice. Additionally, while efforts were made to triangulate data sources, the absence of classroom observations limits insight into how research-informed lessons were implemented in practice. Finally, variation in participants' grade levels, subject areas, and program experiences may have influenced how research was translated into instruction, introducing additional variability in the findings.

Future research should examine how research-informed lessons are enacted in classroom settings through direct observation and measures of student learning. Expanding the sample to include a broader range of programs and participants would strengthen generalizability and allow for comparative analysis across contexts. Additionally, longitudinal studies could explore the sustained impact of teacher research experiences on instructional practice over time.

Final thoughts

Curriculum development is a fluid process, much like engineering research itself. It requires implementation, reflection, revision, and persistence. Through research-based lessons, secondary teachers invite students into engineering practices that many had not previously imagined for themselves. While teachers plant these seeds of inspiration without immediate assurance of outcomes, their work expands students' awareness of STEM pathways and possibilities. In doing so, teachers act not only as curriculum designers, but as translators between the worlds of research and classrooms, shaping experiences whose impact may unfold years later.

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