Supporting Teachers to MASTER Science and Engineering Research Practices

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Abstract

Many secondary teachers often lack experience in actual science and engineering research, as their preparation programs are structured to lead to certification in a particular science field, with science learning constrained to participating in undergraduate lectures and lab courses. As a result, they often hold a view of research through the lens of the traditional scientific method in which research is linear, static, and sterile such that each step is discrete and only occurs when the prior step is complete (Windschitl, 2004; Windschitl et al., 2008). With a focus of NGSS on the science and engineering practices (SEPs), teachers need ongoing professional development that increases their understanding of the ways in which experts do their work and builds their capacity to incorporate these practices into student learning experiences. To address this need, the CSATS Research Experience for Teachers (RET) program introduces teachers to the Modeling Authentic STEM Research (MASTER)model, which serves as a useful tool and intervention for understanding high-level science and engineering research. Therefore, this paper presents an innovative framework that (1) allows teacher educators to create diagrammatic depictions of science and engineering research and (2) enables using these diagrams in programs with teachers. Through the creation of MASTER models, researchers can assist with bridging the communication gap that exists between scientists/ engineers and the K-12 community.

With funding from multiple government agencies, research efforts in science, technology, engineering, and mathematics (STEM) have led to critical discoveries and transformative technological advances and fueled a competitive U.S. economy and national security. The U.S. STEM workforce comprised 36.8 million people in diverse occupations requiring STEM knowledge and expertise in 2021, with the majority working in science and engineering (S&E) or S&E-related occupations (National Science Board, 2024). Scientists seek to study and develop explanations of phenomena in the world around us. Science as a mode of work includes wondering, investigating, questioning, collecting and analyzing data, and sensemaking, which are involved in developing and improving our understanding of the world. Engineers endeavor to apply our understanding of phenomena to solve problems. Engineering is a field that involves imagining novel applications of science and mathematics, creating models or prototypes, and conducting iterative tests and improvements to innovate workable solutions (Cunningham & Kelly, 2017; Johnson et al., 2021). Additionally, science and engineering are both social endeavors that involve human communication, evaluation, critique, and sanction or refutation of knowledge claims and solutions (Schwartz & Crawford, 2004). To advance STEM fields, individuals contributing to science and engineering research require a deep understanding of both a set of epistemic practices and the historical compilation of knowledge (NRC, 2007). Our future success depends on an effective and inclusive STEM education system that prepares a highly skilled STEM workforce and builds STEM literacy for an informed citizenry (Committee on STEM Education, 2018). However, most of the current teacher workforce has little first-hand experience in STEM research, making the shift to preferred methods of epistemic practices-based classroom instruction challenging.

With teachers being expected to incorporate the practices of scientists and engineering into their teaching, professional development programs are needed to increase teachers' understanding of the ways in which experts do their work and to build their capacity to incorporate these practices into student learning experiences (Schwartz and Crawford, 2004; Sadler et al., 2010). The Next Generation Science Standards (NGSS) call for students to learn science and engineering content by engaging in the practices of scientists and engineers, requiring science teachers to have the knowledge and skills needed to meet these standards (NGSS Lead States, 2013). The National Science Education Standards stated that teachers should be "familiar enough with a science discipline to take part in research activities in that discipline" (National Research Council, 1996, p. 60). Further, the resulting instruction enacted by teachers ought to include "approaches that situate learning in authentic problems, model actions of scientists to guide and facilitate students in making sense of data, and support for students to develop their personal understandings of science concepts" (Crawford, 2007, p. 614). These same requirements for teacher knowledge are echoed in *A Framework for K-12 Science Education*:

"Teaching science as envisioned by the framework requires teachers have a strong understanding of the scientific ideas and practices they are expected to teach, including an appreciation of how scientists collaborate to develop new theories, models, and explanations of natural phenomena." (National Research Council, 2012, p. 256)

However, these professional expectations articulated in the *Framework* document are not aligned with the past and current preparation of secondary science teachers in most states (Krajcik et al., 2000; Olson et al., 2015), as past and current programs do not depict the systematic approach of science and engineering research.

While teacher preparation programs are structured to lead to certification in a particular science field per accrediting guidelines (e.g., Council for the Accreditation of Educator Preparation, Association for Advancing Quality in Educator Preparation), secondary science teachers often have a limited understanding of STEM research organization and practices. In contrast to the numerous research opportunities for undergraduate students in STEM majors, these same experiences are often not afforded to preservice secondary science teachers. Their science learning occurs predominantly in undergraduate discipline-based coursework, which tends to focus on content delivery and strict protocol-driven lab experiences with known outcomes (Sadler & McKinney, 2010; Olson et al., 2015). As a result, teachers often perceive science research through the lens of the traditional scientific method, in which research is a uni-directional linear process, such that each step is discrete and only occurs when the prior step is complete (Windschitl, 2004; Windschitl et al., 2008). Further, few states offer teacher certification in engineering or require engineering content for secondary science teacher credentials (Ozfidan & de Miranda, 2017). As such, secondary science teachers often have limited experience with the field of engineering and conflate the technical fields (Antink-Meyer & Meyer, 2016; National Academies of Sciences, Engineering, and Medicine, 2020). Professional development programs need to include interventions that increase teachers' understanding of S&E research practices and build their capacity to incorporate these practices into student learning experiences (Schwartz and Crawford, 2004; Sadler et al., 2010).

The work of the Center for Science and the Schools (CSATS) at Penn State University serves to bridge K-12 education and STEM research performed by science and engineering experts. "CSATS is a STEM education center whose mission is to build mutually beneficial and sustainable relationships between Penn State STEM faculty and K-12 schools to enhance STEM education in PA and nationally" (Ward, 2016, p. 2). The focus of CSATS is to provide professional development that supports teachers in building both their knowledge of science and engineering research and their ability to design learning experiences for pre-college students that mirror or closely approximate the work of STEM professionals.

Leveraging the work of Scientists and Engineers in Teacher Professional Development

Since 2004, CSATS has partnered with university science and engineering faculty to build professional development programs for K-12 educators. CSATS has hosted a range of programs for teachers, including one-day workshops, week-long summer workshops, and a Research Experience for Teachers (RET) program. These programs are designed to enable teachers to both observe and actively participate in the authentic practices of these researchers and develop ways to integrate these practices into innovative curricula.

CSATS's approach to working with researchers focuses on understanding their technical work, with an emphasis on how their research is organized and the epistemic practices that they employ in their research activities. Researchers and their graduate students typically introduce CSATS to their work by presenting a recent conference presentation and providing publications to review. With relevant published articles, CSATS capitalizes on the research questions, investigative methods, and discussions and conclusions to drive future meetings. Through discussions with the Principal Investigator (PI) and the lab group, CSATS becomes familiar with the active research projects underway and how these projects are connected. CSATS faculty also probe for more details on research questions and methodologies, and members of the research group often offer a tour of the lab facilities and demonstrations of their research techniques. These interactions elicit critical ways of thinking and research approaches that are culturally embedded in the research lab, which are included in the professional development program.

CSATS and the researchers co-create activities for the professional development program centered on a particular phenomenon under investigation or an engineering problem. With an understanding of the research, CSATS faculty draw on their knowledge of education standards to identify the audience of the teacher program, including targeted content areas and grade bands. CSATS faculty and members of the technical research team work together to develop the storyline of the program, design activities appropriate for K-12 learners and settings, and identify required materials and equipment. All program elements activities are reviewed, tested, and refined to ensure accessibility of the content and practices for the target audience.

During the CSATS PD programs, which are exclusive to in-service teachers, participants interact directly with scientists and engineers. The work of the scientists and engineers is initially highlighted through researcher talks, which have proven to be extremely valuable. The teachers are also introduced to the NGSS science and engineering practices and how these practices align with the ongoing STEM research. It is during these moments that the teacher participants learn about cutting-edge research and are presented with examples of how researchers rely on collaborative efforts and various methodological approaches to investigate a phenomenon or address an engineering problem. Working in small teams, teachers carry out activities that directly engage them in science and engineering practices to investigate a real-life phenomenon or problem related to the researcher’s work. By completing these activities, teachers are learning first-hand the knowledge and practices required of a scientist or engineer in conducting research. Through guided reflections and discussions on how to translate these practices to the science classroom, program participants are supported to shift their pedagogical perspectives and instructional methods. Learning how to engage with these practices while investigating real-life phenomena and problems transforms teachers’ previous understandings of how learning opportunities should be structured for students to authentically engage in science or engineering.

Not only does the program design drive home the idea that research practices are not sequential, but it also illustrates how a research project can include multiple facets of inquiry. As a concrete way of depicting science and engineering research, CSATS makes use of an intervention – *Modeling Authentic STEM Research (MASTER) Model* – to support secondary-level educators to better understand the research enterprise and to design curricula for their students that mirror or closely approximate the work of STEM researchers.

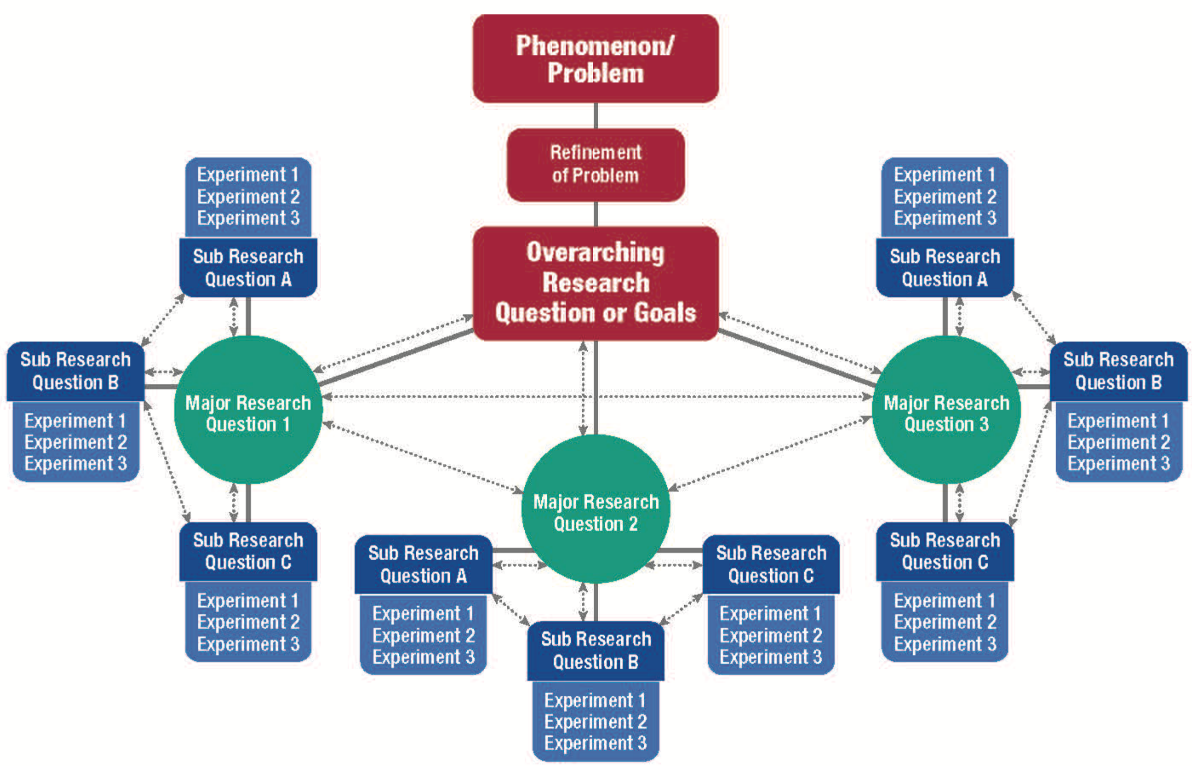
Modeling Authentic STEM Research

The MASTER model is a diagrammatic depiction of a single research project being pursued within a research setting. “[It] combines and applies the crosscutting concepts of systems thinking and model-based reasoning to promote understanding of how researchers do research” (Ward, 2016, p. 5). With its inherent scalability, the diagram can be used to illustrate the work conducted by an individual researcher in a single lab, the complementary efforts involving multiple collaborating researchers, or large, multi-institutional projects involving varied disciplines. This innovative framework has a multi-dimensional structure that characterizes the many processes associated with science and engineering research.

Organization and Components of the MASTER Model

The MASTER model diagram includes a hierarchy such that the broadest ideas about the research reside at the highest levels, with increasingly narrow ideas at lower levels. The model starts with an overarching goal (or research question) at the top that is then broken down into second, third, and even fourth-level tiers, which would be considered sub-components (and sub-subcomponents) of the original research question (Ward, 2016). These sub-components (and sub-subcomponents) consist of more narrowly-focused research questions or goals that relate to the overarching research question and goal, thus demonstrating a detailed framework (Ward, 2016).

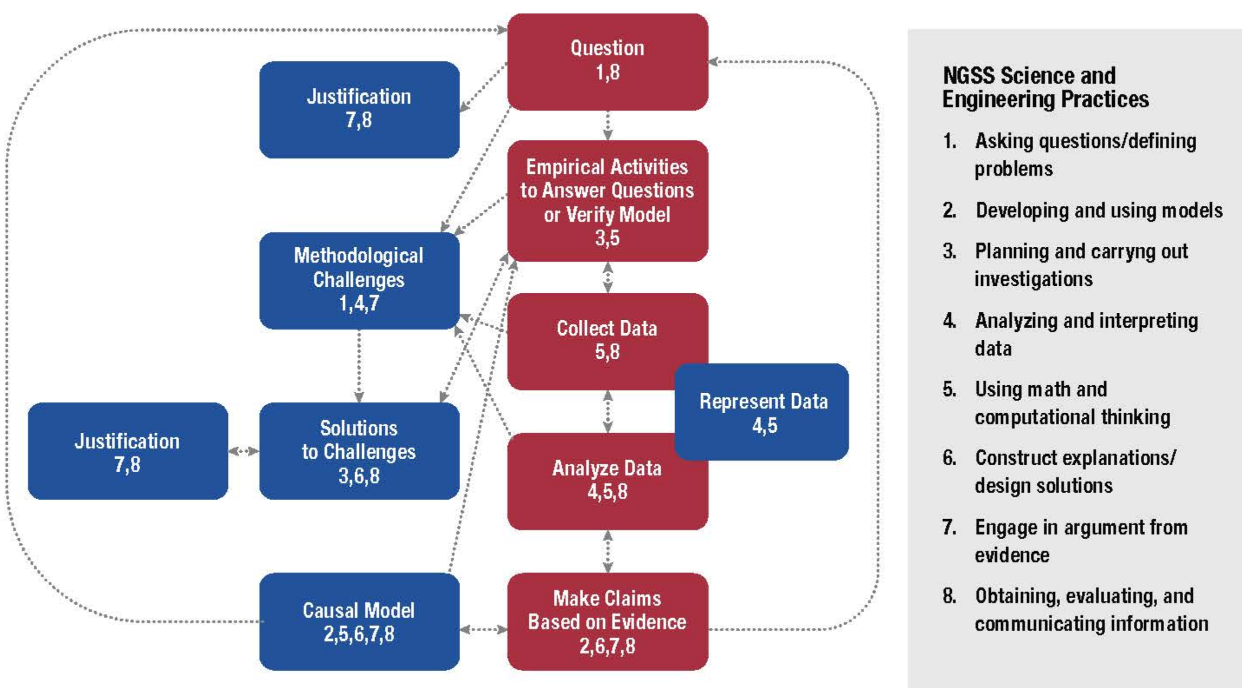
Figure 1
MASTER Model Template



Composed of five distinct levels, the MASTER model depicts aspects of the science and engineering research process. The first level of the model poses the initial research question or design problem created by the researcher, which is then followed by a review of the literature so that, if necessary, the question or problem can be revised (Ward, 2016). The second level of the MASTER model provides a global perspective of the overarching research question or problem with the corresponding research questions/problems (Ward, 2016). In addition, the MASTER model illustrates the connected sub-questions/design problems and the potential experiments that would be performed to address these research questions/design problems (Ward, 2016). The third and fourth levels are focused on the separate but related areas of research created from the previous level. The sub-research questions and corresponding sub-sub-research questions are articulated at these levels (Ward, 2016). The fifth level is known as the "individual experiment level" (Figure 2), and it is at this level where the researcher is performing the methods that are required of their research (Ward, 2016). These methods are aligned with the NGSS science and engineering practices, which reinforces the idea that engaging in these kinds of methods allows students to experience authentic investigations. Most science teachers tend to perceive the actions of a scientist at this lowest level rather than associate the process of research with the many investigations that occur within the same research lab.

Figure 2

Level of the Individual Experiment, Including Connections to NGSS Practices



The MASTER model provides a macro-level view of the various components involved in STEM research. The model depicts the interconnectedness and interdependencies of multiple research activities, which illustrates the amount of collaboration that occurs within a research group. Even though researchers within a lab may be working on separate projects, it is common practice for researchers to share their ongoing work, including data and preliminary findings, and discuss connections between projects. The MASTER model framework has double-sided arrows between the major research questions and sub-questions, thus emphasizing the idea that methodologies and information are shared. Ultimately, this type of lab culture contributes to the success of answering research questions that explain phenomena and solve engineering problems (Ward, 2016).

Strategies for Creating MASTER Models with STEM Researchers

MASTER Models are co-created by CSATS science education faculty and STEM researchers. CSATS forms partnerships with S&E faculty across the university through collaborations on the education activities required by federally funded technical research grants (e.g., Broader Impacts of NSF, education outreach of USDA). If a grant is awarded with funding to support teacher professional development, an initial meeting is conducted remotely (via Zoom), during which CSATS faculty learn about the researcher's goals while simultaneously recording and conducting an in-depth interview. The objective of the interview is to gather enough information to gain an overall perspective of the various research projects that are happening within the researcher's laboratory. The interview takes on the characteristics of two interview types: an informal conversational interview and a general guided approach interview. An informal conversational interview is when "the researcher does not ask any specific types of questions, but rather relies on the interaction with the participants to guide the interview process" (McNamara, 2008; Turner, 2010, p. 755). This interview style is necessary for CSATS to enable the scientist or engineer to explain the ongoing research of their lab. To begin creating the MASTER model, a guided interview approach is used to identify the overarching research question and subsequent diagram components. However, the interview questions can vary based on the person who is conducting the interview and the rapport developed between the interviewer and interviewee. "The ways that questions are potentially worded depend upon the researcher who is conducting the interview" (Turner, 2010, p. 755). During the co-construction of the MASTER Model, questions are asked that support the researcher as they explain their research and allow for CSATS to be flexible in their questioning approach (Turner, 2010).

The first conversation between CSATS and the principal investigator sets the tone for the guided work involved in the co-construction of the MASTER Model. At the beginning of the meeting, CSATS defines their purpose for the interview and explains the format of the MASTER model by showing examples of created MASTER Models. Presenting examples of MASTER Models to the researcher motivates them to share their own research. It also gives researchers a clear understanding of how the MASTER Model is used with teachers who participate in the CSATS programs, especially the CSATS Research Experience for Teachers (RET) program. During this program, teachers learn that the traditional scientific method that has been used within science classrooms is a false perception as to how science research is actually conducted. Therefore, by being shown a completed MASTER Model and an explanation of this tool's usefulness, researchers can begin to understand the long-term impact that the MASTER model can have on teachers.

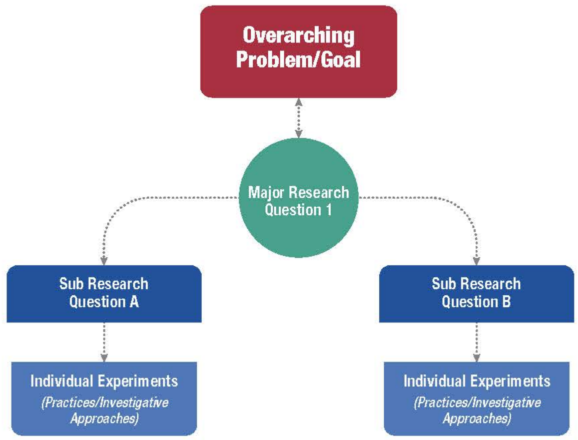
Examining the Benefits of Using an Online Platform

Conducting this interview via an online platform rather than in person has its benefits. For one, the CSATS representative can share their computer screen with the researcher while using an online concept mapping platform (e.g., Miro, Lucid chart, or Canva) to create the MASTER model. This allows the researcher to become invested during the developmental process. By using an online tool*,* a polished color-coded graphic is created that characterizes the researcher's goal through the depiction of circular elements and connecting arrows.This co-construction of the MASTER model begins with the CSATS representative sharing a generic framework of the MASTER model, which includes the following: overarching problem/ goal, sub-problem or goal, sub-sub problem or goal, and the practice/ approach/ strategy (see Figure 2). To aid in the process, the researcher may share some of their own documents with the CSATS representative, which can provide additional information about their research. Another benefit to conducting the interview online is the time-saving aspect. The amount of time to complete the entire MASTER model drastically decreases online. Conducting an interview via an online platform can create a setting where there are little to no distractions for the CSATS representative and the researcher.

If an online platform is not available during the interview, the entire co-construction of the MASTER model and the interview with the researcher can be conducted in person. However, this alternative approach has its limitations, including the extended time required for co-constructing the MASTER model on paper and the additional time needed to transfer the information from paper to a digital format. By comparison, using an online platform to construct the MASTER model improves the overall efficiency of the design process.

Figure 3

Generic Framework of the MASTER Model

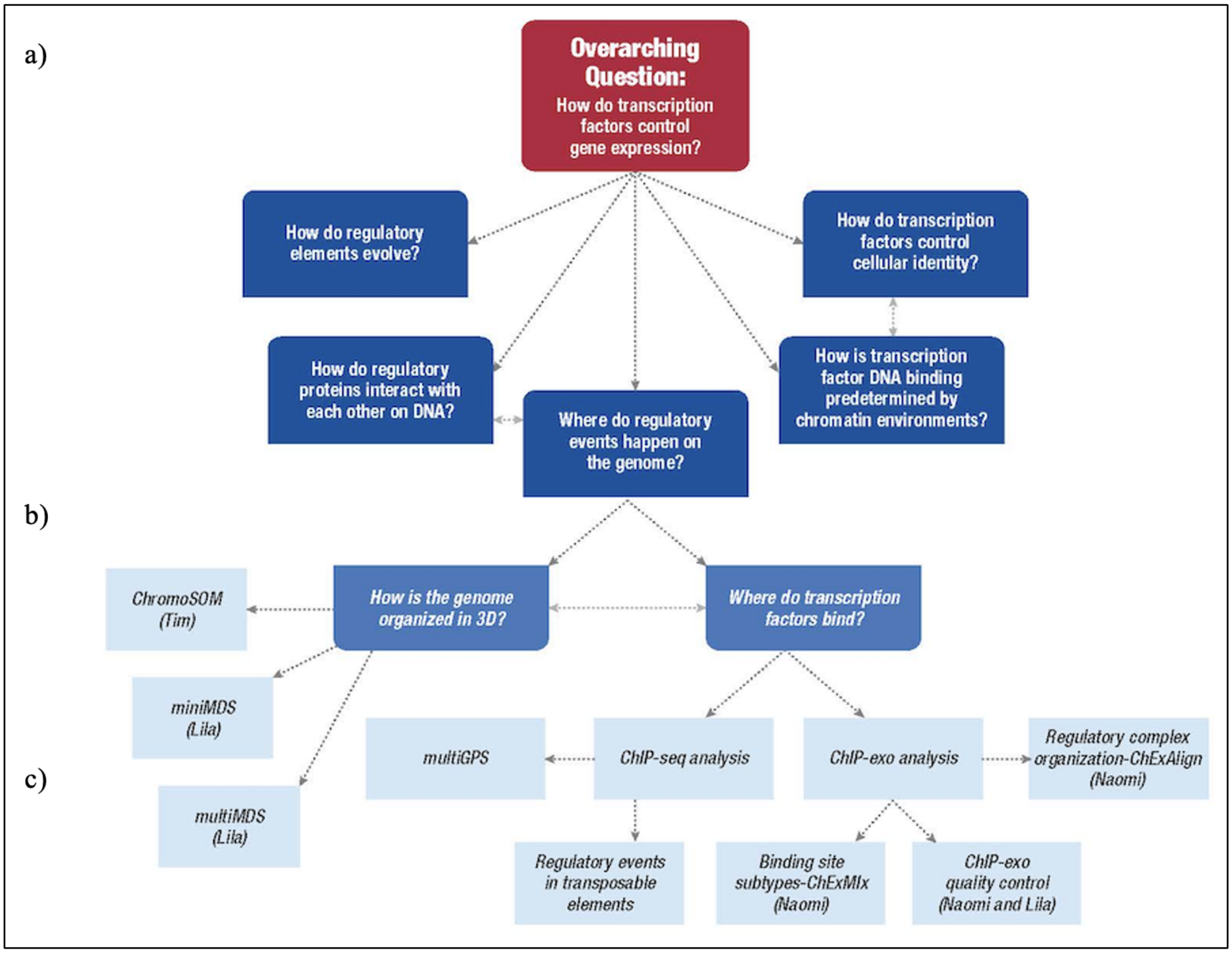


The Interview Process

During the first interview, a draft of the MASTER model is created, which shows the researcher's description of their research. The initial draft begins with defining the conceptual areas within the lab and identifying how these areas are connected. Then, the overarching theme or guiding question of the research is identified. As depicted in the first panel of Figure 4, an example MASTER model shows the research of a computational biologist with the following overarching question: *How do transcription factors control gene expression?*

Figure 4

Example of a MASTER model constructed during the interview process



As the interview progresses in panels (b) and (c), the primary research questions are broken down into connected sub-questions. These additional questions might be derived from the research objectives associated with external funding source(s) for the research. For example, in panel (b), the research question: "*How do regulatory events happen on the genome?"* is broken down into two sub-questions. They are the following: "*How is the genome organized in 3D?"* and "*Where do transcription factors bind?"*

Understanding this relationship makes it easier for the researcher to identify potential research questions during the interview. Some types of questions or suggested probes that could be used by the CSATS representative during the interview are shown in Figure 5:

Figure 5
Potential Interview Questions

Example Question	Rationale
Where would you like to start?	Specify that the construction process can start anywhere.
How would you characterize the work that is being done in your lab?	Use this question to guide researcher to state their specific research goals.
What are the problems within the topic areas?	This can be used as an engineering-based question.
What problems are you trying to address or solve?	This can be used as an engineering-based question.
How do you feel about the development thus far of the MASTER Model?	This question provides insight into the researcher's perception regarding the construction of the MM.
Is the MASTER Model a fair and accurate depiction of your research?	Use this question to determine whether any component of the MM needs to be revised prior to the end of the meeting.

Elements that describe the experimental methods performed in the laboratory are identified and included in the initial draft of the MASTER model (Figure 4 panel "c"). For reference, the MASTER model featured in Figure 4 includes methodological approaches such as "*ChIP-seq analysis*" and "*ChIP-exo analysis*" used to investigate where transcription factors bind. Finally, arrows are added to indicate connections between research activities that can inform work in other areas of the research.

Once the initial draft is edited, the secondary draft is completed, and the researcher is presented with this copy. At this point, the researcher is given the opportunity to review the MASTER model and provide feedback for additional edits. The edits can range from fine-tuning some of the research questions to elaborating on methodological techniques displayed within the MASTER model. A follow-up interview will be conducted (if necessary) to capture more details or information. Once both of the parties (the CSATS representative and the researcher) are satisfied with the working draft, a final MASTER model is produced.

Using the MASTER Model to Introduce Research to Teachers

Secondary STEM in-service teachers of varying levels of expertise are presented with the MASTER model during summer professional development (PD) programs (e.g., CSATS summer RET program, CSATS week-long summer workshops) to gain a deeper understanding of science and engineering research. CSATS partners with various Penn State research labs (e.g., architectural engineering, cancer, bioinformatics, and acoustics) to ensure that teacher participants have an opportunity to learn about cutting-edge research that directly correlates to their area of science teaching. Prior to the start of the summer PD programs, CSATS faculty meet with researchers to co-construct MASTER models. These MASTER models are used by the science/ engineering faculty during the PD as they introduce the teachers to their research agendas. Participating teachers are encouraged to develop their own MASTER models, particularly those in the CSATS summer RET program, to depict their individual summer research projects. Teachers are guided through the series of fundamental steps necessary to create their own MASTER model. These steps include the following: (1) identifying an anchoring phenomenon, problem, or gap in understanding, (2) identifying the overarching research question or goal, (3) developing a number of sub-questions or goals that would contribute to addressing the overarching question or goal, (4) breaking down the sub-questions into sub-sub questions or goals, and finally (5) identifying the methodological approaches that one would use in order to complete the research project. By constructing a MASTER model, teacher participants can obtain a deeper understanding of the science and engineering research process. Once their MASTER model is complete, the teachers can recognize similarities between their own MASTER model and the researchers' MASTER models. For teachers in the CSATS RET program, comparing the two diagrams allows them to identify where they fall within their mentor's work and to make the connections between their individual projects and the multiple research projects being performed within the larger research group. The following is a statement from a past RET participant regarding their perceptions of their researcher's MASTER Model:

As I review his MASTER model, I'm able to make connections to all of the presentations I observed from the different members of the lab in our weekly lab meetings, as well as make connections to our numerous conversations…Now that I see [my mentor's] MASTER model, he did a wonderful job scaffolding my learning! I'm so excited to see that I focused on the transcription factors! It is evident that he presented my research experience based upon his MASTER model (Jessica's RET survey response, August 2020)

Clearly, being shown their researcher's MASTER model aided in this teacher's learning experience. Furthermore, this teacher filled in the existing gaps that pertained to their understanding of the team's research. This teacher's revelation supports the idea that the MASTER model is a unique framework that allows one to visualize the multiple projects and authentic research practices that occur within one laboratory. In the next statement, another RET participant describes their overall impressions of their researcher's MASTER Model:

Creating the Master Model gave me focus as to what I was doing and the purpose of my research. During my initial time during the research faze, I really wasn't sure how my project connected and I felt stressed and not sure about what I was doing and why (didn't have a definite direction). Once I saw how my project fit in to the big picture I felt more confident in what I was doing and my stress lessened and I could ask better questions and work more efficiently (Holly's RET survey response, August 2020).

In a similar fashion, this teacher was able to see how their research fit within their researcher's work. Furthermore, this teacher's statement highlights the usefulness of the MASTER model.

As with any intervention, one should consider the advantages and the disadvantages of the process. There are several advantages of using the MASTER model as an educational teaching tool. First, this intervention not only provides a teacher with a global perspective as to the interconnectedness that exists within a research group, but it also illustrates how the science and engineering practices are heavily ingrained within authentic science and engineering research. Secondly, teacher educators who wish to use this intervention for their own specialized programs (that strive to bridge research to teacher practice) can easily adopt and implement this framework. The MASTER model is not a difficult intervention to duplicate. Lastly, the MASTER model disrupts the notion that science and engineering research will be performed in a step-by-step, linear process.

The primary challenge of the MASTER model is that it can require a significant amount of time to construct an appropriate model. Since this is an iterative process, teachers are constantly having to adjust and refine their model as they engage in the research experience. This is largely because new information is being gathered daily and can influence the construction of this model. In the following statement, a RET teacher elaborates on how building a MASTER model can be a tedious process:

I'm a planner and need to see the big picture, so this process allows for that opportunity. It is a challenging process, because it took a lot of time to understand the extremely detailed research and content going on in the lab, so it wasn't a straightforward process for me. The expectations were very clearly modeled and now that I have the experience, it would be easier to go back and add details (Jessica's RET survey response, August 2020)

After learning how MASTER models depict technical research, teachers are introduced to the process of creating a Classroom Research Project (CLRP) plan using the MASTER model. The primary objective of creating a CLRP MASTER model is to support teachers to integrate their newly developed knowledge, as it pertains to research, into their curriculum.

CLRP MASTER Models

Professional development focused on S&E practices is critical for teachers to develop curriculum and provide instruction that promotes authentic science and learning experiences for students. The MASTER Model is an intervention that can be used by teachers to create a CLRP plan as they attempt to develop innovative ways to bridge STEM research to educational practice. Teachers participating in the PD are guided through the process of creating a CLRP MASTER model. First, they are tasked with identifying three essential elements of the classroom research project: (1) key ideas within the research to be conducted by students, (2) new content that would need to be integrated within their existing curriculum, (3) the foundational concepts that make-up their existing curriculum, and the S&E practices that students will use during the project. Identifying these components allows the teachers to integrate their newfound knowledge within the existing curriculum. A past RET teacher participant comments on this process:

It helped to [specifically] list the science involved and the connections between them and also between the research project. [The CLRP Master Model] enabled me to see the connections between topics and activities that I need to make in my lesson (Susan's RET survey, August 2020)

The final version of the CLRP MASTER model mirrors the structure of the research MASTER Model and includes the overarching research question, the primary research questions that the students will attempt to address, and the investigative approaches for each of the primary questions.

In summary, engaging in the process of constructing a research MASTER model and a CLRP MASTER model can be beneficial. Teacher educators who work alongside scientists and engineers should adopt this intervention because the MASTER model not only informs teachers of the science and engineering practices but also refines their teaching methods in ways that better reflect the work of scientists and engineers.

Discussion and Conclusion

Secondary science teachers generally have limited interactions to engage in authentic research with scientists and engineers (Ward, 2016) and need support to integrate these research practices into learning experiences for their students. Science teachers traditionally have not been afforded the opportunity to experience an authentic research experience (Krim et al., 2019). Instead, most teachers are limited to their past experiences and more familiar ways of teaching, which consist of performing cookie-cutter labs (Ward, 2016) and attending science content lectures. Neither engages educators in authentic investigations that enable them to translate research practices into the pre-college science classroom as called for by NGSS. Additionally, many teachers lack a full understanding of the NGSS engineering practices (Schwarz et al., 2017). The MASTER model has proven to be an effective tool for teacher educators in science education. Serving as candid depictions of the research process, these detailed schematics illustrate the practices of scientists and engineers and support teachers to have their students experience the actual practices of science and engineering practices performed in the real world (Hill et al., 2018, 2019; Jackson & Hill, 2021; Johnson & Hill, 2021). By viewing the interconnectedness of different research questions, teachers can see that science and engineering research is collaborative and not a siloed process. MASTER models also increase teachers' understanding of the practices that drive the work of investigating phenomena and solving problems. Therefore, by deepening their understanding of the way that scientists and engineers work, teachers will begin to understand how science and engineering practices should be integrated into their curriculum plans. The MASTER model allows teachers to visualize how multiple science and engineering practices can occur throughout the investigation process. As mentioned by Schwarz et al., 2017, when these practices come together within an investigation, one can then engage in the process of sensemaking, which is a way to characterize how one would "make sense of the world" (p. 6). By transforming the teaching practices of science educators, the MASTER model stands to be a tool for addressing issues of equity within the science classroom because it supports teachers who are choosing to turn away from traditional teaching methods that marginalize students of Color. Therefore, the use of the MASTER model in professional development influences a teacher's pedagogical content knowledge and changes how they choose to teach science in the classroom.

As the gap continues to exist between STEM research and classroom instructional practice, teachers need support to improve their instructional approach. The MASTER model is an intervention that enables teachers to design a curriculum that allows students to experience the process of investigating real-life phenomena and solving engineering problems. By focusing on improving the instructional capabilities of science teachers, we can directly impact the future of science education. Furthermore, students who choose to pursue a teaching career would have a better model to rely on for their teaching methods. Instead of emulating a traditional teaching style or relying on the scientific method, these future teachers would possess the know-how to ensure that their students mirrored the authentic practices of scientists or engineers. The MASTER model is a valuable framework that should be utilized to support critical pedagogical shifts within science teacher education.

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