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Equipping Science Teachers to Support Student Motivation in NGSS Classrooms:

Insights from the Development of the M-PLANS Program

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Summary

The Next Generation Science Standards (NGSS) put forth an aspiring call for science educators to enact instructional experiences that enable all students to participate in the real-world practices of science. To achieve this, teachers need to create classroom environments that will attract all students to science learning and support and sustain their motivation and engagement. This report describes key insights from a collaboration among motivation experts, science education researchers, and middle school science teachers who used a research-based approach to develop a professional learning program with classroom-based resources to promote and sustain students' motivation and engagement for science learning.

The Motivation - Planning Lessons to Activate eNgagement in Science (M-PLANS) program aims to equip science teachers to support students' motivation and engagement in NGSS-based instruction. The program includes a suite of professional learning tools and resources to facilitate middle school science teachers' design, modification, and implementation of instruction that fosters robust and meaningful science learning. Resources include a set of motivationally supportive strategies for science classroom use. The M-PLANS collaborative team iteratively developed and tested the tools and strategies in middle school science classrooms. Insights from this research and development phase of M-PLANS indicate that teachers benefited from increased knowledge about how to integrate motivation principles into their science teaching practice. Additionally, students generally perceived their teachers as using the instructional practices aligned with the M-PLANS training. These perceptions were, in turn, associated with students' higher levels of positive motivational beliefs.

Introduction

Why student motivation and engagement matters for science learning

How can we support teachers in meeting the call of NGSS to enable all students to feel included, empowered, and interested to learn science?

This is an exciting time for science education where there has been dedicated effort toward transforming the teaching and learning of science to promote access and broaden opportunities for all students. The Framework for K–12 Science Education (the Framework; National Research Council, 2012) and the Next Generation Science Standards (NGSS Lead States, 2013), for example, put forth an ambitious call for science educators to enact instructional experiences that will enable their students to participate in the real-world practices of science. The underlying idea is that engaging in scientific activity—such as designing and carrying out investigations, collecting and making sense of data, weighing claims and evidence, and reporting and debating results—encourages students to actively think about, integrate, and apply what they know. As students do this, they learn how scientists make sense of the natural world, and they learn that science is an active quest to enhance one's understanding.

Realizing the promise of the Framework and the NGSS rests on teachers creating instructional experiences in which students are highly engaged and active in their learning. In today's science classrooms, students are asked to go beyond just learning facts about a science topic and toward figuring out and explaining how or why something happens in the natural world. This means that it is not solely what students know but also how they use and apply their knowledge that really matters for science learning.

While this vision for science learning is more authentic to the discipline and stands to deepen students' proficiency with science, it also places higher demands on students in terms of participation, personal responsibility for learning, and intellectual effort in the classroom. For instance, students are expected to exercise curiosity and interest as they develop and use models to explain phenomena; work collaboratively to conduct investigations and discuss their evidence and findings; and weigh evidence, evaluate claims, and engage in scientific argumentation about their own and others' ideas. This learning format is very different from the more typical science classroom experience of students mainly learning factual content directly from either the teacher or a textbook. Without teachers' thoughtful attention to motivation, students are unlikely to realize the gains in science proficiency that the Framework and the NGSS intend to promote.

To effectively support student motivation, teachers need to both leverage and value students' background knowledge and experiences and connect these to rigorous science learning. Teachers must also be attentive to their own pedagogy and how their teaching actions interact with students' motivation and performance. Moreover, they need to plan instruction that will attract all students, especially those whose backgrounds have been historically underrepresented in STEM, to science learning and actively engage them in practices of doing science.

Currently, there are very few resources available to teachers to help them support and sustain students' motivation and engagement with ambitious NGSS instruction. Yet, science teachers identify addressing students' motivation as one of their most pressing needs (Weis, 2013). The Motivation - Planning Lessons to Activate eNgagement in Science (M-PLANS) program aims to help science teachers support students' motivation and engagement in NGSS-based instruction to foster robust and meaningful science learning. The professional learning program was developed by a collaborative team of experts in STEM motivation and science education from Michigan State University, the University of Nevada Las Vegas, and WestEd. As part of this effort, the M-PLANS team has been developing and testing motivationally supportive strategies that teachers can readily learn and implement in their lesson planning and instruction.

This report provides an overview of the motivation design principles that form the foundation of M-PLANS, a description of the resources and tools that were developed for the program, and an illustration of the development and research cycle that guided the effort. Key insights from the research and development effort are discussed. The report concludes with implications and next steps for the program.

M-PLANS Program Overview

The M-PLANS program aims to contribute to systemic change in science instruction by shifting motivational processes from an implicit element of educating students to an explicit and intentional set of instructional strategies that teachers can enact. The direct benefit is that the program equips middle school science teachers to better leverage students' knowledge and experiences during instruction, thereby expanding opportunities for meaningful learning to all students, including those who may be on the periphery of science participation, those whose backgrounds have been underrepresented in science education and careers, and those who may be reluctant to invest in science learning. The program aims to achieve this by providing a professional learning approach with effective classroom strategies that teachers can readily learn and implement in their lesson planning and instruction. The program includes concrete resources for teachers to reflect on and improve their own classroom practices so that they, in turn, can interact productively with students and achieve the critical goal of broadening access and opportunity for the full range of students they teach.

Motivation Design Principles

The M-PLANS professional learning program aims to enhance teachers' knowledge about how to support student motivation in a variety of ways so all students can effectively participate in NGSS classrooms. To accomplish this, M-PLANS uses five theoretically and empirically based motivation design principles (MDPs; Linnenbrink-Garcia et al., 2016; Marchand et al., 2022; Patall et al., in press). These MDPs translate general motivation principles into science-specific instructional practice so that teachers can more readily embed them in their science instruction. Figure 1 describes each MDP, with accompanying reflective questions that teachers can use to incorporate each MDP into their lesson planning and instruction.

Figure 1. M-PLANS Science-Specific Motivation Design Principles

MDP	Design Principle	Sample Metacognative Planning Questions
Belonging	Support feelings of relatedness and belonging within the classroom community and the larger science community by promoting inclusion and helping all students to identify with science	How does this lesson extend an invitation into science for all students? How am I connecting this lesson to my students' experiences outside the classroom and checking that I am not sending explicit or implicit messages about who does and does not belong in science?
Confidence	Support students' confidence for science through instruction that includes clear expectations; challenging work that is calibrated to the knowledge, skills, and abilities of students; and informational and encouraging feedback	What kind of specific feedback should I anticipate giving that will draw students' attention to strategy use and potential for improvement? How will I communicate that I believe every student can do the work? How will I encourage students if they perceive the assignment to be too challenging?
Learning Orientation	Emphasize growth in three-dimensional learning and understanding as the goal of science learning, rather than rote learning, grades, competition, or social comparison	What opportunities does this lesson provide for students to engage in challenging reasoning, making sense of phenomena, designing solutions, revising their thinking, and/or reflecting on their understanding?
Autonomy	Support students' autonomy through opportunities for student decision-making and direction during science instruction, such as in the context of investigations of phenomena and solving problems	How can I challenge myself to promote student autonomy in this lesson in ways that enhance students' development as science learners? How will these autonomy supports help students make sense of phenomena and/or design solutions to problems in this lesson?
Relevance	Consider students' perspectives and provide science learning opportunities that students find personally meaningful, interesting, and/or culturally relevant	What is taking place in the world of local communities right now that I can draw on in relation to the phenomenon or design problem of interest? Are there opportunities to connect students' in-class learning to these current events or issues and/or give assignments an authentic context?

Importantly, these design principles advance the goal of making science accessible and valuable to a diverse student body by encouraging teachers to consider their students, actively learn about who their students are, and remain attuned to their students throughout the school year. As teachers take up these practices and use the MDPs as heuristics in planning and instruction, they should be better able to create learning environments that invite all of their students into science to learn about phenomena that are interesting and important to them.

Resources & Tools

The M-PLANS program includes a multi-week professional learning approach that is supported by a comprehensive reference toolkit and pocket-sized, classroom-based quick tools that teachers can use in their lesson planning and to make just-in-time instructional decisions.

Professional Learning Approach

The M-PLANS program incorporates four themes from contemporary perspectives on teacher learning: (1) first-hand experience is foundational to learning new classroom practices; (2) teacher learning requires thoughtful reflection involving planning, monitoring, and reflecting on experiences; (3) teachers, like all adult learners, benefit from dialogue with colleagues aimed at developing common understanding and support; and (4) professional learning is shaped in important ways by the context in which teachers work. Organized around these main themes, the M-PLANS program engages teachers in an interactive process of collaboration, enactment, and reflection focused on designing lessons and implementing motivationally supportive instructional strategies that are informed by and appropriate for their unique school and classroom contexts. Teachers attend an initial professional learning institute to be introduced to the program, followed by ongoing support during the school year via a professional learning community that promotes collective inquiry and reflective dialogue. A primary goal of the professional learning is to enhance teachers' knowledge and capability to select and implement instructional strategies that are timely, flexible, and responsive to their students' needs.

Reference Toolkit

The toolkit is a comprehensive reference guide to aid teachers in their planning and instruction while they are working to incorporate the motivation principles into their teaching. The toolkit explores the reciprocal relationship between motivationally supportive teaching and equitable science instruction. It also includes guidance on general classroom organization, routines, policies, and climate considerations—all of which provide a vital foundation for supporting motivation in science classrooms. For each MDP, the toolkit provides a set of "look-fors" that describe science classrooms that are either more aligned or less aligned with the MDP, planning questions to consider specific strategies for enacting the MDP, activities that align with the MDP, and "talk moves" that teachers might use when enacting the MDP. Finally, the toolkit describes connections between the MDPs and phenomenon-centered science instruction, crosscutting concepts, and science and engineering practices that are cornerstones of the NGSS.

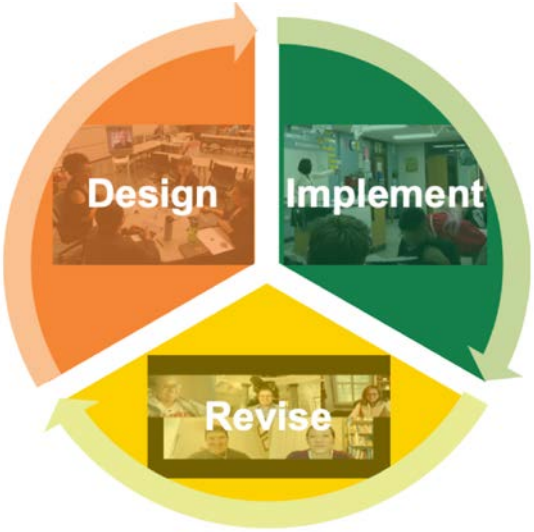
Classroom-Based Quick Tools

The M-PLANS quick tools include pocket-sized flip-books and activity cards designed for teachers to use as just-in-time supports while planning and teaching. They serve as easy-to-read instructional companions that scaffold the consistent use of strategies and help teachers incorporate these strategies into their daily teaching routines. Flip-books provide a manageable set of strategies and talk moves related to each MDP, including motivationally supportive strategies matched with specific NGSS science and engineering practices. Activity cards describe high-impact instructional strategies that incorporate multiple MDPs, with the aim of supporting teachers in integrating the MDPs in a seamless manner.

M-PLANS Development and Research

The early development of the M-PLANS program was based on best practices in teacher professional learning and informed by a co-design process that sought to bring research and practice closer together. As part of the development process, the team worked closely with science teachers to design a program with concrete strategies that can be put into daily practice. The process was iterative and involved a series of design-implement-revise cycles (Figure 2). This iterative process spanned 3 years, starting with the initial design and development of the professional learning approach by the research team, followed by cycles that involved co-design with participating science teachers and district-level science coordinators. During each cycle, the team worked with teachers to study the program features as they were implemented in classrooms, then used what was learned to inform the next round. This process enabled the team to continuously move toward a more refined and usable set of resources for teachers.

Figure 2. M-PLANS Development Cycle



Studying Teachers' Implementation of M-PLANS

During development, the M-PLANS team collected data from a variety of sources on teachers' uptake of the MDPs and their use of M-PLANS resources and tools. The data sources included lesson observations, interviews, teacher focus groups, and pre- and post-implementation teacher surveys. In interviews and surveys, teachers were asked to reflect on their efforts to incorporate MDPs into their planning and teaching, the usability of the resources and tools, and the extent to which M-PLANS supported changes in their teacher–student interactions. Across all classrooms, lesson observations were video recorded so that the development team could examine how MDPs were translated into practice. More than 20 science teachers across 12 racially and ethnically diverse middle schools contributed to the development process.

The team also investigated how students reacted to instruction from teachers who participated in the M-PLANS program via end-of-class self-reports, pre- and post-implementation student surveys, and end-of-unit Knowledge-in-Use (KiU) assessment tasks. End-of-class self-reports and post-implementation surveys asked students to report on the degree of teacher support they perceived related to the MDPs as well as their own science motivation. A pre-implementation survey asked about different aspects of students' science motivation. This survey was used in tandem with the post-implementation surveys to examine changes in students' motivation and engagement as a result of the program. The KiU assessment included a set of scenario-based tasks that required students to use aspects of disciplinary core ideas, science and engineering practices, and crosscutting concepts to make sense of phenomena in a constructed-response format. Outcomes from the KiU assessment were used to examine associations between teachers' supportive practices (student-reported) and students' science performance.

Key Insights from the Development of M-PLANS

Insights from this research and development effort indicate that teachers benefited from increased knowledge about how to integrate motivation principles into their science teaching practice. For example, teachers reported that they had greater awareness of student motivation and how to support and sustain it. They also reported that implementing the MDPs was both feasible and impactful. In addition, students generally perceived their teachers as using the instructional practices emphasized by the M-PLANS program, and these perceptions were, in turn, associated with students' higher levels of positive motivational beliefs. Noteworthy is that analyses also suggest that some forms of teacher uptake of MDPs appeared to reduce potential barriers to student engagement in science. For example, instructional practices aligned to the Belonging MDP were associated with significant declines in students' perception that studying science required too much effort and was too threatening to one's self-esteem.

Analysis of classroom video recordings showed that different teachers often enacted the same MDP in different ways and in varying situations, suggesting the value of the M-PLANS comprehensive, flexible, and context-driven approach to teacher instructional decision-making. While teachers strongly agreed that each of the MDPs was useful for their teaching, they also perceived some barriers to consistent implementation, including how to routinize strategies learned in the M-PLANS program so that they become part of daily practice and how to calibrate the use of MDPs so they are maximally beneficial during lessons. As the M-PLANS program moves out of the early development phase toward wider implementation and study, the team will continue to use evidence from classrooms to further modify and refine the program features and supports.

- Teachers reported high levels of knowledge about and use of instructional practices for supporting student motivation after participating in the M-PLANS professional learning program.
- Teachers reported that the M-PLANS resources were very usable and useful in their instructional planning and classroom practices.
- Students reported that their teachers provided motivationally supportive instruction, which was in turn related to higher student motivation and engagement in science learning.

Implications & Next Steps

The M-PLANS program aims to equip science teachers to support students' motivation and engagement in NGSS-based instruction. The five MDPs upon which M-PLANS is based, along with the companion supports for reflection, planning, and practice, are designed to promote research-based strategies that are flexible enough to meet the needs of diverse student populations but structured enough to scaffold consistent use. Noteworthy is that each teacher who has participated in the program has integrated the motivation design principles into their instruction in their own ways (see, for example, Liu et al., 2023a). This is possible because they are principles, not prescriptions, for instructional design and teaching. They are meant to be used flexibly by teachers to meet the diverse needs of their unique sets of students.

This report described the overall M-PLANS program and core features and reported key insights from the development cycle. Results from the early development phase indicate that the M-PLANS program can be a companion to a range of NGSS-designed curricula, can be used by teachers with various levels of experience, and shows promise with student populations representing diverse backgrounds (Liu et al., 2023b; Mouzaoir et al., 2023). As the program moves out of early development and continues to mature and increase in scale, it will be important to implement and study the M-PLANS program with a broad range of middle school science teachers and across varying school contexts. This will contribute to the evidence base on the program's promise for scalability and for impact on teacher beliefs and practices as well as on students' motivation, engagement, and learning.

The M-PLANS program has the potential to contribute to systemic change by moving motivational processes from an implicit element of science instruction to an explicit and intentional set of strategies teachers can enact. As students develop positive motivational beliefs about science, they may be more likely to develop a sense of identity and belonging with science, interest and empowerment in science learning and careers, and better overall proficiency with science.

Taken together, results from the early development phase indicate that the M-PLANS program can be a powerful companion to a range of NGSS-designed curricula, can be used by teachers with various levels of experience, and shows promise with student populations representing diverse backgrounds.

The M-PLANS team is interested in reciprocal research-practice partnerships with districts to benefit science teachers and students. To learn more, visit https://m-plans.org/.

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