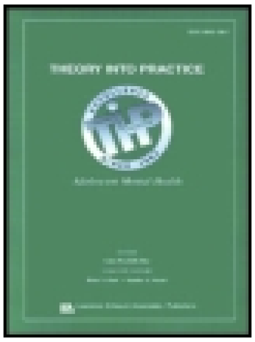

Theory Into Practice

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/htip20

Lessons from a co-design team on supporting student motivation in middle school science classrooms

Gwen C. Marchand, Jennifer A. Schmidt, Lisa Linnenbrink-Garcia, Christopher J. Harris, David McKinney & Pei Pei Liu

To cite this article: Gwen C. Marchand, Jennifer A. Schmidt, Lisa Linnenbrink-Garcia, Christopher J. Harris, David McKinney & Pei Pei Liu (2021): Lessons from a co-design team on supporting student motivation in middle school science classrooms, Theory Into Practice, DOI: 10.1080/00405841.2021.1932155

To link to this article: https://doi.org/10.1080/00405841.2021.1932155

Published online: 24 Jun 2021.

THEORY INTO PRACTICE
https://doi.org/10.1080/00405841.2021.1932155

Lessons from a co-design team on supporting student motivation in middle school science classrooms

Gwen C. Marchand[a], Jennifer A. Schmidt[b], Lisa Linnenbrink-Garcia[b], Christopher J. Harris[c], David McKinney[a], and Pei Pei Liu[b]

[a]Department of Educational Psychology and Higher Education, University of Nevada, Las Vegas, Nevada, USA; [b]Department of Counseling, Educational Psychology, & Special Education, Michigan State University, East Lansing, Michigan, USA; [c]Science and Engineering Education Research, WestEd, San Francisco, California, USA

ABSTRACT

Decades of motivation research have yielded a set of Motivation Design Principles (MDPs) that can be leveraged to support the development of student motivation and engagement in the classroom. This article addresses the translation of these guiding principles to teacher professional learning and subsequently, classroom practice. Drawing from published literature, as well as the experiences of a co-design team of motivation and science education researchers and middle school science teachers, we address the landscape of decision points for designing and implementing professional learning focused on supporting middle school students' motivation in science. We identify 3 key decision points: (1) the extent to which professional learning should focus on general principles or specific practices; (2) the appropriate level(s) for translation of the MDPs into practice; and (3) the creation of opportunities for teacher reflection and self-assessment of their practice on student motivation and engagement.

Researchers and educators face a multitude of questions during translation of theory to practice, including, but not limited to, the following: What are the most effective professional learning contexts for teachers to learn about education theory? To what extent should researchers be involved in the day-to-day implementation of practice? How prescriptive or flexible should translational materials be? At what level (e.g., classroom, student, task) do theoretical applications make the most sense? How do educators know if these applications are effective? Decisions made around these types of questions are instrumental in developing effective engagement opportunities for educators and students during the translation of theory into practice.

Drawing from published literature, as well as experiences of a co-design team of motivation and science education researchers and middle school science teachers, we address the landscape of decision points for designing and implementing professional learning (PL) focused on supporting middle school students' motivation in science. Decision points coalesce around 3 distinct, yet related aspects of classroom application of motivation theory. First, we describe a process for considering the extent to which professional learning focuses on general theoretical principles or more concrete practices aligned

CONTACT Gwen C. Marchand Gwen.marchand@unlv.edu University of Nevada, Las Vegas, 4505 S. Maryland Pkwy, Las Vegas, NV 89154.

with theory. Next, we describe how the translation of motivational supports can unfold at multiple levels of the classroom system, ranging from general classroom climate supports to instructional supports targeting individual student motivation. Finally, we address the creation of opportunities for teacher reflection and self-assessment of their practice on student motivation and engagement.

Motivational theory as a foundation for instructional practice

Motivational Design Principles (MDPs)

Our work as a co-design team is framed around 5 Motivational Design Principles (MDPs, Linnenbrink-Garcia et al., 2016) representing a theoretically integrated approach to supporting student motivation. The principles draw upon decades of empirical research that identify major classes of motivational variables and the corresponding instructional strategies that support each type of motivation. Linnenbrink-Garcia et al. (2016) noted the importance of creating instructional environments to support the motivational constructs of perceived competence beliefs and expectancies, effort attributions and growth mind-sets, value and interest during academic learning, intrinsic motivation, mastery goal orientations, and positive emotions. They argued for 5 unifying design principles that cut across different research traditions and perspectives to support these multiple forms of motivation and positive emotion.

Below, we briefly describe each MDP, highlighting key ways in which we supported teachers' enactment of the MDP within the context of our co-design process. Table 1 presents a summary of the broad definition of each MDP and the key theoretical connections and constructs on which each MDP is based. A shorthand name for each MDP is provided in Table 1 and is used as the reference throughout the remainder of the paper.[1] Each MDP is composed of a set of specific principles for supportive instruction and are described in the following paragraphs.

The MDP, *Competence*, refers to instruction that supports students' positive perceptions of competence by providing clear expectations to students and communicating clear goals for learning (both at a lesson or unit level as well as with respect to specific assignments). The principles in this MDP also touch on provision of challenging work and how teachers might guide and support students through strategies such as providing examples and modeling. *Competence* principles also involve supporting students through informational and encouraging feedback that is specific and focuses on effort attributions.

The MDP *Autonomy* includes instructional design principles related to allowing students to make choices that are meaningful and consequential to learning and providing students opportunities to direct their own learning. Other instructional principles that fall within this MDP include providing rationales and support rather than using controlling language or actions and taking steps to acknowledge student perspectives.

Strategies that support the broad MDP of *Relevance* include making connections to students' previous experiences, interests, goals, cultural backgrounds, and real lives. Teachers working with this MDP are encouraged to use exciting and/or enjoyable activities to draw students into further inquiry and learning. The

Table 1. Theoretical roots of the motivation design principles.

Shorthand Name	Principles Guiding Instructional Design	Theoretical Connections & Key Constructs	Exemplar references
Competence	Support perceived competence through well-designed instruction, challenging work, and informational and encouraging feedback.	Social Cognitive Theory (self-efficacy)	Bandura (1997); Schunk and DiBenedetto (2020)
		Expectancy-Value Theory (achievement expectancies)	Eccles and Wigfield (2020)
		Self-Determination Theory (need for competence)	Ryan and Deci (2017)
		Academic Self Concept	Marsh and Martin (2011)
		Goal-setting Theory	Locke and Latham (2002)
Autonomy	Support students' autonomy through opportunities for student decision making and direction	Self-Determination Theory	Ryan and Deci (2017)
		Social Cognitive Theory (students are agents who can select & create environments for themselves)	Bandura (1997)
		Stage-environment fit (agency & independence as key developmental tasks)	Eccles et al. (1993)
Relevance	Select personally relevant, interesting activities that provide opportunities for identification and active involvement.	Expectancy-Value Theory (subjective task values)	Eccles and Wigfield (2020)
		Self-Determination Theory (autonomous behavior suggest personal value & importance)	Ryan and Deci (2017)
		Theories of interest development	Hidi and Renninger (2006)
		Culturally relevant/responsive education	Gay (2002); Ladson-Billings (1995); Aronson and Laughter (2016)
Mastery Orientation	Emphasize learning and understanding and de-emphasize performance, competition, and social comparison	Attribution Theories (attributions of academic success & failure)	Graham (2020)
		Theories of Intelligence (incremental vs. fixed beliefs about ability)	Dweck (1999)
		Achievement goal theories (mastery goal orientation)	Ames (1992)
Belonging	Support feelings of relatedness and belonging among students and with teachers	Self Determination Theory (need for relatedness)	Ryan and Deci (2017)
		Attachment theory	Ainsworth and Bowlby (1991)
		Belongingness motivation	Baumeister and Leary (1995)

This table summarizes the theoretical roots of the MDPs as articulated in Linnenbrink-Garcia et al. (2016) and Patall et al. (in press). In the material provided to teachers, the MDP of *Competence* was referred to as *Confidence* and the MDP of *Mastery Orientation* was referred to as *Learning Orientation*. These changes were made due to recommendations from co-design teachers.

Relevance MPD includes the principle of incorporating current events and issues related to the learning topic.

The *Mastery Orientation* MDP includes the principle of emphasizing student reasoning, sense making, and deep understanding as the goal of learning activities, rather than producing the right answer, complying with instructions or rules, or working to outperform other students. Teachers leverage strategies that use evaluation and feedback practices that focus on deeper content understanding/reasoning and student effort and strategy use. The *Mastery Orientation* MDP encourages teachers to model the commitment to learning and growth they are expecting from students, while de-emphasizing social comparison and competition.

Finally, the *Belonging* MDP emphasizes strategies that support feelings of relatedness and belonging within the classroom community. Toward this end, teachers work to develop warm, caring relationships with students. To support a community of peers in the classroom, teachers also encourage peer connection and model support, trust, and equality for student-student interactions. This MDP includes the principle of illuminating ways that students might identify with individuals within their classroom community and also with the learning domain, communicating an inclusive view of who belongs in the domain (e.g., science).

For each supportive action, there are also instructional actions that can undermine motivation, creating opportunities for maladaptive responses to develop in the classroom context. For the purposes of this paper, we focus on the supportive aspects of each MDP to highlight the positive elements of translating theory into classroom practice. For a more inclusive and comprehensive discussion of the theoretical and empirical roots of the MDPs see Patall et al. (in press) and Linnenbrink-Garcia et al. (2016).

Engagement as a proximal outcome of motivational design

Our work with teachers centers student engagement as the most immediately observable student outcome resulting from the instructional strategies implicated by the 5 MDPs (with broader changes in motivational beliefs and student learning as more distal outcomes). Most of the theories undergirding the MDPs frame deeper engagement in learning tasks as 1 key manifestation of higher motivation, and research conducted from these various theoretical orientations has largely supported this assertion empirically. For example, increased engagement is predicted by higher levels of self-efficacy (Salanova et al., 2011), positive academic self-concept (Guo et al., 2016), intrinsic or autonomous motivation (Taylor et al., 2014), interest (Beymer et al., 2020), mastery goal orientation (Urdan & Kaplan, 2020), relatedness with teachers and peers (Furrer & Skinner, 2003), and teacher autonomy support (Flunger et al., 2019).

While researchers define engagement in many different ways and at many different grain sizes (see Christensen et al., 2012), the term *engagement* resonates deeply with educators and represents something teachers believe they can readily observe and influence in their classrooms (e.g., “Are students engaged in the learning activity I planned for today?”). Our discussions with teachers have generally focused on classroom engagement, or engagement in particular learning activities, rather than school engagement or engagement with broader prosocial institutions. During these discussions, we worked to identify how teachers perceive engagement and asked them to think about engagement as reflective of the quality of student immersion with classwork as demonstrated by student behaviors, emotional displays, cognitive involvement, and social interactions during learning tasks (see Skinner & Pitzer, 2012). Our work with teachers to identify and implement motivationally-supportive strategies has included assessing student engagement as a means for teachers to check the efficacy of the strategies they are implementing.

Shaped by context: MDPs enacted in middle school science classrooms

Researchers have argued that academic motivation emerges from transactions amongst individual characteristics like cognitions and beliefs, interpersonal relationships and social experiences in school, and community or classroom environments (Turner & Patrick, 2008). When thinking about how to design for motivation, educators must consider how to support students situated within unique learning settings (Bembenutty et al., this issue; Nolen et al., 2015), including the disciplinary context. In this article, we draw from our initial enactment of the M-PLANS (Motivation — Planning Lessons to Activate eNgagement in Science) project to discuss decision points for supporting teachers' design of motivationally-supportive science instruction. The M-PLANS project took place in 6 middle school science teachers' classrooms from 3 different school districts, together representing a diverse student population, using 3 different curricula designed to align with the Next Generation Science Standards (NGSS: NGSS Lead States, 2013).

The *Framework for K-12 Science Education* presents a vision for science and engineering education in which students actively use and apply the 3 dimensions of disciplinary core ideas, crosscutting concepts, and scientific and engineering practices to make sense of phenomena and find solutions to problems (National Research Council [NRC], 2012). As educators reconfigure their classrooms and their lesson plans to support these 3 dimensions of science learning, they must also recognize that this new vision places higher demands on students in terms of participation, personal responsibility for learning, and intellectual effort (NRC, 2015). For example, in an NGSS-focused design project to construct and test a device that either releases or absorbs thermal energy by chemical processes, we observed students investigate and then develop and carry out a plan to protect an endangered species of desert tortoise by designing an incubator for safely transporting tortoise eggs to safe havens. In this instructional unit, students took on the responsibility for asking questions and defining the problems that would help solve this design challenge which was based on a real-world issue related to an endangered tortoise whose habitat included the students' city and surrounding areas. Students worked in small groups which required them to participate more and take on greater responsibility. Working collaboratively, students designed and conducted investigations that involved using and applying their chemistry, biology, and engineering knowledge and skills to iteratively design an incubator that met the criteria and constraints of the challenge. The project culminated with students writing to a local conservation organization to share their designs with an explanation of their design decisions and a description of how their incubators work. In design challenges like this one, students are active participants in the direction of their learning and are responsible for making sense of phenomena and using and applying their knowledge to solve design problems. This format of instruction is much different from doing typical lesson activities, where students are primarily responsible for learning either directly from the teacher or textbook.

The motivational demands of NGSS-aligned science classrooms are embedded within the broader set of challenges characterizing middle school. The middle school shift to more consistent, rigorous and formal science instruction occurs during a developmental period characterized by enhanced propensity for interest exploration, expression of choice, and increased capacity for higher-order thought. However, middle schools traditionally provide fewer opportunities for active participation in learning and enhance feelings of isolation, leading to a mismatch that can contribute to motivational declines (Eccles et al., 1993). Accordingly, instructional strategies and practices that foster and maintain the active engagement called for by the *Framework* during this vulnerable period in student development are critical for maintaining motivation.

Decision points for motivational design

In addition to considering the need for heightened engagement during NGSS-based science instruction, we also drew upon contemporary theories of adult learning (Guskey, 2002; Rohlwing & Spelman, 2014) in designing our M-PLANS project. The ultimate goals of the PL were sustained change in teacher knowledge, beliefs, and attitudes toward motivationally-supportive instructional practices, which are most likely to occur as a result of an iterative process involving construction of knowledge, change in teacher behaviors and observation of student outcomes (Guskey, 2002). Through our PL approach, we engaged in a continuous process of collaboration, enactment, and reflection (Krajcik et al., 1994) around the design of teachers' lesson plans, informed by and appropriate for each unique school and classroom context. Thus far, this iterative process has spanned 2.5 years, starting with initial design and development of the PL by the research team and followed by cycles of co-design with participating science teachers and district-level science coordinators (see Table 2 for project activity timeline). Through this process, the team encountered decision points that led to considerable change to the PL approach to be responsive to teacher needs and experiences. For example, rather than provide a template for lesson planning, we developed an extensive toolkit to be used flexibly by teachers while planning lessons; this toolkit also helped teachers respond "on-the-fly" to perceived motivational challenges during instruction. We discuss the decisions around the initial design and revision below to illustrate some of the considerations for translation of motivation theory into classroom applications.

Decision point 1: Broad principles or concrete strategies?

A central tenet of the M-PLANS project is to support teachers' flexible application of the MDPs. Rather than a prescriptive translation of MDPs into classroom actions, we initially developed PL focused on broad principles, providing a range of examples of the enactment of each MDP in "real world" science classrooms. The broad principle perspective aimed to support teachers' thinking about a motivationally-supportive classroom using a comprehensive lens that integrated multiple MDPs. By taking this holistic perspective, we hoped to emphasize that motivational support was not an add-on, but an integral element of effective instruction. This PL design perspective was also aimed at supporting teachers' skills to select the MDP(s) that most closely fit particular lessons, which requires a conceptual understanding of the principles. Concurrently, we believed that teachers would

Table 2. Timeline of major co-design activities.

Activity	Products/results	Time frame
Design initial tools for learning about and applying MDPs	Initial PL model Lesson planning template Lesson screener Engagement assessment	Fall 2018 — Spring 2019
Co-design professional learning institute focused on supporting teachers' understanding of the MDPs and beginning re-design of chemistry unit (work is continued by teachers independently)	Feedback on initial tools resulting in substantial revision of some, elimination of 1 (lesson screener), and creation of a new tool (brief list of concrete strategies)	4 full days in early Summer 2019
Refresher workshop prior to unit implementation	Discussion of revised tools, teacher training to reflect on student engagement	Half day in Fall 2019, prior to unit implementation
Teachers implement re-designed units, record their instruction & reflect on students' engagement during these lessons. Regular meetings with researchers to get feedback and set goals for ongoing implementation.	Teachers have opportunity to reflect on their teaching in structured ways; opportunities and challenges to implementing MDPs are revealed	9–11 weeks in Fall/ Winter 2019–2020
Institute to reflect on implementation and revise tools	Direction for revision of tools	2 days in Spring 2020
Refinement of tools, including creation of comprehensive toolkit describing each MDP and examples of how teachers can plan and implement, for use in rollout phase with new teachers	Tools are further revised and developed	Spring2020 — Winter 2021

need flexibility in determining how to apply the MDP in a way that was most useful for their particular classroom and instructional goal.

Through the co-design process, the team regularly revisited this decision. It was clear that as teachers gained experience working with the MDPs, they grew increasingly comfortable with the principles. They adopted language from the principles when communicating with the M-PLANS team and their peer teachers about the importance of creating classrooms that support motivation. When academic language related to the MDPs created a barrier for communicating effectively with each other and their students, the co-design teachers offered terminology changes. Through our work with the co-design teachers, we revised the "short-hand" names of the design principles to further teachers' understanding of the underlying principles (e.g., competence changed to confidence; mastery orientation became learning orientation; the original labels were retained in the current manuscript for conceptual clarity). Teachers seemed to benefit from having a shared vocabulary around these complex issues and a community of practitioners with whom to reflect on their practice.

Despite teachers' gains in understanding and using the broad principles, it became apparent that more specific strategies and actions would be helpful when actually implementing the MDPs in instructional planning and delivery. Though teachers often intended in their planning to implement a variety of MDPs in their instruction, their execution was often limited to the concrete examples provided in the PL and they seemed to struggle with comprehensive and consistent implementation. For example, one teacher who always read texts aloud to the whole class drew on principles from the *Autonomy, Belonging*, and *Competence* MDPs to design a strategy to make it safer for his students to admit a lack of comprehension: groups would elect a spokesperson to share out words the group wanted explained. However, he did not allow time for groups to confer with each other before asking whether anyone had questions, and he also only paused to solicit these questions once before he continued reading. More specific strategies and talk moves may have provided clearer guidance for this teacher about how to more effectively design his instruction to support these three MDPs.

As we worked through the initial phase of developing and implementing different PL materials, we decided to revise the materials to both build knowledge of the general principles and provide more concrete and specific recommendations for embedding motivational supports in practice. Teachers found the lesson planning template too constrictive and not compatible with their district-provided curricular materials and were thus reluctant to use the template beyond their participation in the project. So rather than encouraging practice changes through the use of a lesson planning template that emphasized foundational knowledge of the MDPs, we developed a toolkit that included both conceptual and concrete guidance for teachers (see Table 3 for examples related to the *Mastery Orientation* MDP). The toolkit includes an *overview*, which is a summary of each MDP with definitions and guiding principles; *look-fors*, which are brief vignettes of classroom practice illustrating "more-like" versus "less-like" application of each MDP to help teachers visualize what the MDP looks like in practice; a *planning tool*, which is a set of metacognitive self-reflection questions that teachers can pose to themselves to help them consider specific strategies for enacting the MDPs in upcoming lessons; concrete *activities* and instructional strategies that align with each MDP; and *talk moves*, which are sample sentence/question stems and discourse moves that teachers might say when enacting each MDP.

Table 3. Examples of toolkit elements aligned to the *Mastery Orientation* MDP.

Element	Example	
Description of MDP	**Mastery Orientation Principle**: Emphasize student reasoning, sensemaking, and developing a deep understanding as the goal of activities, rather than producing the right answer or complying with instructions	
Looks more like this/less like this	**Looks less like this . . .** The teacher presents students with overly simplistic, one-dimensional learning tasks that focus on surface demonstrations of understanding, producing answers without explanation, adhering to a pacing guide, or following instructions.	**Looks more like this . . .** The teacher provides students with challenging, authentic science work that requires sustained effort and thinking and the use of all three dimensions of NGSS to explain phenomena or design solutions. Tasks are sufficiently open-ended to allow multiple answers or approaches, and group tasks are designed to foster authentic collaboration by requiring multiple perspectives or multiple roles.
Self-reflection questions	What opportunities does this lesson provide for students to engage in challenging reasoning/scientific sense-making, revising their thinking, and/or reflecting on their understanding?	
Strategies and activities	Build in pauses during or at the end of class, or small revision/modification/iteration cycles in classroom activities to allow students to reflect individually on how their thinking has changed and/or raise questions about what they are learning. This helps students integrate their new knowledge and reminds them that their focus should be on developing deeper understanding, rather than completing activities.	
Talk moves	"What's your evidence for that?" "How do you know that?" "What did you see/observe that makes you think that?" "Is that evidence sufficient? Are there other kinds of evidence that could support our claim?"	
Strategies aligned to Science and Engineering Practices: Asking Questions and Defining Problems	Create structures/practices in the classroom that provide opportunities for students to pose questions that drive learning. This helps remind students that the overall purpose of their endeavors in science class is to develop a greater understanding of phenomena. For example: ● Use a Driving Question Board: Have students list what they are curious about regarding a phenomenon or what interests them, and then use that to generate scientific questions that can be investigated. Post the question(s) the students are trying to answer and consistently return to them throughout the unit, asking the class what questions have been answered and what new questions have arisen along the way.	

The MDP of *Mastery Orientation* was referred to as *Learning Orientation* in the toolkit materials provided to teachers.

We also added a section describing how the MDPs can support the NGSS vision for science education in which students are engaged in making sense of phenomena and solving design problems using the three dimensions of disciplinary core ideas (DCIs), science and engineering practices (SEPs), and crosscutting concepts (CCCs). This section provides guidance to teachers about integrating the MDPs with the selection of phenomena or design problems and the use of CCCs. It also provides specific strategies for supporting student motivation and engagement when enacting the 8 SEPs (see final row of Table 3 for an example), as we realized that the SEPs provided an important context for enacting the MDPs. For example, we discovered that concerns about producing the "right" results led some teachers to undermine autonomy and mastery goals during investigations. Identifying specific strategies that could help teachers support these motivational constructs through applying appropriate MDPs within the SEP of Planning and Carrying Out Investigations helps teachers view these motivational supports as an integral part of scientific practice, not something to be "added on" when convenient. We believe these concrete aspects can be used flexibly to enhance and reinforce teacher learning about motivationally-supportive instruction.

Decision point 2: What is the most appropriate focal level (e.g., classroom, lesson, or task) for translating the MDPs into practice?

Although the original intent of the project was to develop PL related to task-specific and lesson-specific motivational supports, we discovered that the teachers who were most successful at supporting motivation were drawing from a strong foundational classroom climate, which we had not explicitly covered in the PL. Conversely, some teachers struggled to support motivation effectively because their lesson-specific strategies were undermined by the prevailing classroom climate. Implementing task-level motivationally-supportive strategies are more likely to be successful when the classroom organization, norms, and expectations also establish a positive classroom climate (Turner & Meyer, 2000).

A supportive climate is important for several reasons. First, motivational strategies involving peer-to-peer interactions require a culture of trust and respect (Hymel & Katz, 2019). For example, autonomy-support strategies may involve having students work together to solve problems, share their ideas and justifications for solutions, and offer diverse perspectives. These types of interaction are more likely to succeed when teachers clearly delineate communication expectations and model respectful communication through their own interactions with students, acting as the "invisible hand" for shaping communication expectations (Kindermann, 2011). Second, students are more likely to take academic "risks" when they believe that trying new solutions and making mistakes are norms valued by their classroom community (Beghetto, 2009). For example, in promoting understanding, teachers may provide opportunities for students to make their thinking visible in an effort to promote reflection, revision, and extension into new avenues through gallery walks, think-aloud opportunities, and small group think-pair-share structures that involve peer critique prompts. When divergent views and perspectives are viewed as valuable to a healthy science community, students may be more likely to fully engage in these strategies. Next, inviting students to participate in developing the classroom community (e.g., taking classroom roles, developing rules, shaping displays in the classroom) helps students view the science classroom as a place where they belong and can exercise voice (Farmer et al., 2019). Finally, the creation of an explicitly inclusive and equity-focused classroom, serves to "invite in" all students, enhance feelings of belonging, and ensure that curriculum and instruction is meaningful for students (Kumar et al., 2019). Embracing an equity focus creates an environment where MDPs can be responsive to diverse needs and address factors that may otherwise lead to marginalization in science. For example, strategies and actions associated with supporting belonging touch on supporting the development of a science identity, but also ask teachers and students to directly confront myths about who "does" science.

To situate the specific MDPs within a broader frame of positive classroom climate and equity, we developed two new aspects of the PL focused on (1) classroom climate and (2) equity. First, we included a module in the PL institute and the toolkit on developing a positive classroom climate. This module was based on our observations of several of our co-design teachers, who created supportive classroom climates at the beginning of the school year prior to beginning their unit-based MDP implementation. For example, one of our co-design teachers supported belonging and autonomy at the beginning of the year by introducing the idea of a "classroom circle" with her students. She asked students to generate a list of what they needed or liked to have in a classroom to feel safe, respected, and productive. Students shared their ideas and agreed on which qualities belonged inside a "classroom circle," which was then drawn on a poster hung at the front of the room and referred back to periodically throughout the year as a set of community norms endorsed by the class. In addition to cultivating a sense of community, these norms supported more autonomous regulation throughout the year, as the teacher reminded students to abide by their own community compact instead of relying on more controlling forms of classroom management.

Further, although we view the MDPs as helpful for supporting the motivation of diverse learners, our original work did not hold an explicit equity focus. Thus, we also developed an equity preamble to the toolkit to ask teachers to consider how designing for motivation also designs for equity. We determined that the work would have greater impact if teachers were asked to explicitly consider equity and address inequity when implementing motivational supports (see also Archer et al., this issue). For example, we identified seeing science as disconnected from personal identities or daily life as a challenge to student motivation that is related to inequity in science learning. We highlighted the MDP of *Relevance* as a way to conceptually frame a starting place for teachers to act on this inequity. The MDP is focused on explicitly connecting science content to students' individual identities and experiences, but when students recognize that science can help them answer questions about real-world phenomena that are important to them and their community, this also helps to dispel perceptions that science belongs to only the majority culture. Teachers can make minor changes, such as asking for students to provide examples of the way they see the phenomena in their own lives, or to offer synonyms or multi-lingual phrases or interpretations of concepts to validate students' knowledge, to both support motivation and equity.

Decision point 3: How to support teacher self-assessment and reflexivity?

Robertson et al. (2020) described their vision for an agentic approach to professional learning that included leadership, autonomy, intentionality, and reflexivity. Reflexivity can be established a number of ways during a PL program, involving critical feedback cycles amongst leadership and development team members, amongst leadership team members and participating teachers, between peer teachers, and within individual teachers (Robertson et al., 2020). Thus, we established processes for iterative feedback cycles that reflect each of these targets.

Our co-design process involved 3 cycles of classroom implementation of motivational supports. During the implementation, we collected artifacts (e.g., planning materials), recorded classroom instruction, administered an end-of-class report to students about their perceptions of their own engagement during the day's lesson, and asked teachers to evaluate students' engagement in the day's class. Recorded data were coded for motivational supports by researchers and teachers on the co-design team. After each cycle, teachers met individually with a research partner to review data and discuss the process of using the MDPs. These meetings provided feedback to the research team about what worked well and areas for additional support as teachers engaged in the MDP enactment. The meetings also supported teachers' self-reflection as they considered how their knowledge, beliefs, and practices evolved during each cycle. For example, one teacher found it challenging to avoid the use of controlling language as emphasized from the *Autonomy* MDP. Through these reflection meetings, he was able to reframe his prompts by adding "what do you think?" Students seemed to feel more comfortable generating answers and sharing with their classmates with this change in language. This broad principle was daunting for this teacher to implement, but the concrete strategy provided a subtle shift that enabled him to more effectively implement the MDP. After the unit implementation, a series of meetings with co-design teachers highlighted the importance of these self-reflection meetings. Encouraged by these examples, we developed a peer mentoring program and guide, designed to utilize and extend the more robust and specific toolkit (described in *Decision Point #1*) to facilitate peer teacher support for implementing MDPs. To assist teachers in meaningful reflection about whether their implementation of the MDPs was successful on a given day, we also developed (and revised through the co-design process) the REACT (Review of Engaged Action in the Classroom for Teachers). This brief checklist helped teachers assess the student behaviors, emotional displays, indicators of cognitive involvement, and social participation that signal student engagement during a particular lesson. Our co-design teachers noted that the REACT helped them carefully evaluate their instruction at the end of the lesson and consider changes for future lessons.

Implications for educators

In addition to the decision points, we identified considerations for science educators who may want to instantiate the MDPs in their own classroom practice. We have found that although there are many benefits to integrating the MDPs into pedagogy and practice, the shift to doing so requires time for planning, enactment, and thoughtful reflection. With this in mind, we suggest that teachers who are new to using the MDPs take a measured approach and begin on a smaller scale in order to build their own competence.

We suggest that teachers approach these MDPs in a way that is flexible, personal, and forgiving. Changing teaching practice can be difficult and takes time. The way that teachers approach their content, the relationship that teachers have with their students, and teacher preferences for different strategies will influence the choices that teachers make in terms of how they interpret the MDPs. There is no "one size fits all" when it comes to motivational support. A good place to start is by selecting 1 or 2 MDPs on which to focus. Select a few talk moves or strategies to try out. See what happens when you enact these, reflect, and plan adjustments or new strategies to try next. Allow time for new strategies to become routines and set time aside to reflect on how to revise those strategies. Trying out different activities, talk moves, and strategies, and adjusting if students do not appear to respond or the new support feels awkward over repeated use is important. Just as important is identifying strategies already being used that undermine motivation and working to remove them from regular practice over time. Finding a consistent set of strategies that works for each teacher will go a long way toward sustainable implementation.

In addition to using the toolkit described here, working with a critical friend or friends can create a safe and supportive space in which to do this work. Ongoing collaborative conversations and planning helps build understanding and shared strategies for integrating motivational supports into instruction. Through thoughtful, iterative application of the MDPs, teachers can develop instructional strategies aligned with the MDP that fits with their approach to teaching and their unique classrooms.

Final thoughts

Facilitating the translation of general guiding principles to instruction that supports student motivation, reflexive process that enables teachers to gain knowledge, confidence, and skill over time. Designing instruction to support student motivation and engagement may necessitate a multi-level approach, which includes laying the foundation for a positive classroom climate to maximize the uptake of specific strategies. Through our M-PLANS experience, we learned that explicitly designing instruction that is aligned with motivational theory in the context of NGSS-based science instruction is more likely to be sustained when the PL approach is tied to creating a fundamental shift in beliefs about existing instructional planning and strategies while also providing content-specific instructional strategies that support the broader MDPs.

Note

1. When referencing the design principles by their shorthand names throughout the paper, we present them as capitalized and in italics to distinguish them from the motivational constructs with similar names.

Acknowledgments

The authors wish to thank the participating school districts, co-design teachers, science coordinators, and students for their partnership and insights on this project. The authors gratefully acknowledge Katherine Nilsen and Gary Weiser from WestEd for their contributions to the research and development work. This work would not be possible without the contributions of the undergraduate and graduate student research team members of the M-PLANS project.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This material is based upon work funded by the National Science Foundation under grant numbers 1813047, 1812976, 1907480. Any opinions, findings, and conclusions or recommendations expressed herein are those of the authors and do not necessarily reflect the views of the National Science Foundation.

ORCID

Gwen C. Marchand http://orcid.org/0000-0003-1337-6296
Jennifer A. Schmidt http://orcid.org/0000-0003-2853-9801
Lisa Linnenbrink-Garcia http://orcid.org/0000-0003-4857-9229
Pei Pei Liu http://orcid.org/0000-0001-6057-2084

References

Ainsworth, M. D. S., & Bowlby, J. (1991). An ethological approach to personality development. *American Psychologist*, *46*(4), 333–341. https://doi.org/10.1037/0003-066x.46.4.333

Ames, C. (1992). Classrooms: Goals, structures, and student motivation. *Journal of Educational Psychology*, *84*(3), 261–271. https://doi.org/10.1037/0022-0663.84.3.261

Archer, A. F., Kumar, R., & Pilcher, E. (this issue). Using expectancy value theory to examine the cultural costs to preservice teachers of color. *Theory into Practice*.

Aronson, B., & Laughter, J. (2016). The theory and practice of culturally relevant education: A synthesis of research across content areas. *Review of Educational Research*, *86*(1), 163–206. https://doi.org/10.3102/0034654315582066

Bandura, A. (1997). *Self-efficacy: The exercise of control*. W.H. Freeman. https://doi.org/10.1891/0889-8391.13.2.158

Baumeister, R. F., & Leary, M. R. (1995). The need to belong: Desire for interpersonal attachment as a fundamental human motivation. *Psychological Bulletin*, *117*(3), 497–529. https://doi.org/10.1037/0033-2909.117.3.497

Beghetto, R. A. (2009). Correlates of intellectual risk taking in elementary school science. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *46*(2), 210–223. https://doi.org/10.1002/tea.20270

Bembenutty, H., Schunk, D., & DiBenedetto, M. (this issue). This issue: Applications of motivation research to practice. *Theory into Practice*.

Beymer, P. N., Rosenberg, J. M., & Schmidt, J. A. (2020). Does choice matter or is it all about interest? An investigation using an experience sampling approach in high school science classrooms. *Learning and Individual Differences*, *78*, 101812. https://doi.org/10.1016/j.lindif.2019.101812

Christensen, S. L., Reschly, A. L., & Wylie, C. (2012). *Handbook of research on student engagement*. Springer.

Dweck, C. S. (1999). *Self-theories: Their role in motivation, personality, and development*. Taylor & Francis.

Eccles, J., Midgley, C., Buchanan, C., Wigfield, A., Reuman, D., & MacIver, D. (1993). Development during adolescence: The impact of stage/environment fit on young adolescents' experiences in schools and families. *American Psychologist*, *48*(2), 90–101. https://doi.org/10.1037/0003-066x.48.2.90

Eccles, J. S., & Wigfield, A. (2020). From expectancy-value theory to situated expectancy-value theory: A developmental, social cognitive, and sociocultural perspective on motivation. *Contemporary Educational Psychology*, *61*, 101859. https://doi.org/10.1016/j.cedpsych.2020.101859

Farmer, T. W., Hamm, J. V., Dawes, M., Barko-Alva, K., & Cross, J. R. (2019). Promoting inclusive communities in diverse classrooms: Teacher attunement and social dynamics management. *Educational Psychologist*, *54*(4), 286–305. https://doi.org/10.1080/00461520.2019.1635020

Flunger, B., Mayer, A., & Umbach, N. (2019). Beneficial for some or for everyone? Exploring the effects of an autonomy-supportive intervention in the real-life classroom. *Journal of Educational Psychology*, *111*(2), 210–234. https://doi.org/10.1037/edu0000284

Furrer, C., & Skinner, E. (2003). Sense of relatedness as a factor in children's academic engagement and performance. *Journal of Educational Psychology*, *95*(1), 148–162. https://doi.org/10.1037/0022-0663.95.1.148

Gay, G. (2002). Preparing for culturally responsive teaching. *Journal of Teacher Education*, *53*(2), 106–116. https://doi.org/10.1177/0022487102053002003

Graham, S. (2020). An attributional theory of motivation. *Contemporary Educational Psychology, 61*. https://doi.org/10.1016/j.cedpsych.2020.101861

Guo, J., Nagengast, B., Marsh, H. W., Kelava, A., Gaspard, H., Brandt, H., Cambria, J., Flunger, B., Dicke, A.-L., Häfner, I., Brisson, B., & Trautwein, U. (2016). Probing the unique contributions of self-concept, task values, and their interactions using multiple value facets and multiple academic outcomes. *AERA Open*, *2*(1), 1–20. https://doi.org/10.1177/2332858415626884

Guskey, T. R. (2002). Professional development and teacher change. *Teachers and Teaching: Theory and Practice*, *8*(3), 381–391. https://doi.org/10.1080/135406002100000512

Hidi, S., & Renninger, K. A. (2006). The four-phase model of interest development. *Educational Psychologist*, *41*(2), 111–127. https://doi.org/10.1207/s15326985ep4102_4

Hymel, S., & Katz, J. (2019). Designing classrooms for diversity: Fostering social inclusion. *Educational Psychologist*, *54*(4), 331–339. https://doi.org/10.1080/00461520.2019.1652098

Kindermann, T. A. (2011). Commentary: The invisible hand of the teacher. *Journal of Applied Developmental Psychology*, *32*(5), 304–308. https://doi.org/10.1016/j.appdev.2011.04.005

Krajcik, J. S., Blumenfeld, P. C., Marx, R. W., & Soloway, E. S. (1994). A collective model for helping middle grade science teachers learn project-based instruction. *The Elementary School Journal*, *94*(5), 483–497. https://doi.org/10.1086/461779

Kumar, R., Karabenick, S. A., Warnke, J. H., Hany, S., & Seay, N. (2019). Culturally Inclusive and Responsive Curricular Learning Environments (CIRCLEs): An exploratory sequential mixed-methods approach. *Contemporary Educational Psychology*, *57*, 87–105. https://doi.org/10.1016/j.cedpsych.2018.10.005

Ladson-Billings, G. (1995). Toward a theory of culturally relevant pedagogy. *American Educational Research Journal*, *32*(3), 465–491. https://doi.org/10.3102/00028312032003465

Linnenbrink-Garcia, L., Patall, E. A., & Pekrun, R. (2016). Adaptive motivation and emotion in education: Research and principles for instructional design. *Policy Insights from the Behavioral and Brain Sciences*, *3*(2), 228–236. https://doi.org/10.1177/2372732216644450

Locke, E. A., & Latham, G. P. (2002). Building a practically useful theory of goal setting and task motivation: A 35-year odyssey. *American Psychologist*, *57*(9), 705–717. https://doi.org/10.1037/0003-066X.57.9.705

Marsh, H. W., & Martin, A. J. (2011). Academic self-concept and academic achievement: Relations and causal ordering. *British Journal of Educational Psychology*, *81*(1), 59–77. https://doi.org/10.1348/000709910X503501

National Research Council. (2012) . *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*.

National Research Council. (2015) . *Guide to implementing the next generation science standards*. The National Academies Press.

NGSS Lead States. (2013) . *Next generation science standards: For states, by states*. The National Academies Press.

Nolen, S. B., Horn, I. S., & Ward, C. J. (2015). Situating motivation. *Educational Psychologist*, *50*(3), 234–247. https://doi.org/10.1080/00461520.2015.1075399

Patall, E. A., Linnenbrink-Garcia, L., Liu, P., Zambrano, J., & Yates, N. (in press). Instructional practices that support adaptive motivation, engagement, and learning. In J. Reeve (Ed.), *Oxford handbook of educational psychology*. Oxford University Press.

Robertson, D. A., Padesky, L. B., & Brock, C. H. (2020). Cultivating student agency through teachers' professional learning. *Theory into Practice*, *59*(2), 192–201. https://doi.org/10.1080/00405841.2019.1705090

Rohlwing, R. L., & Spelman, M. (2014). Characteristics of adult learning: Implications for the design and implementation of professional development programs. In L. E. Martin, S. Kragler, D. J. Quatroche, & K. L. Bauserman (Eds.), *Handbook of professional development in education: Successful models and practices, preK-12* (pp. 231–245). Guilford Press.

Ryan, R. M., & Deci, E. L. (2017). *Self-determination theory: Basic psychological needs in motivation, development, and wellness*. Guilford Publications.

Salanova, M., Llorens, S., & Schaufeli, W. B. (2011). "Yes, I can, I feel good, and I just do it!" On gain cycles and spirals of efficacy beliefs, affect, and engagement. *Applied Psychology: An International Review*, *60*(2), 255–285. https://doi.org/10.1111/j.1464-0597.2010.00435.x

Schunk, D. H., & DiBenedetto, M. K. (2020). Motivation and social cognitive theory. *Contemporary Educational Psychology*, *60*, 101832. https://doi.org/10.1016/j.cedpsych.2019.101832

Skinner, E. A., & Pitzer, J. R. (2012). Developmental dynamics of student engagement, coping, and everyday resilience. In S. L. Christenson, A. L. Reschly, & C. Wylie (Eds.), *Handbook of research on student engagement* (pp. 21–44). Springer.

Taylor, G., Jungert, T., Mageau, G. A., Schattke, K., Dedic, H., Rosenfield, S., & Koestner, R. (2014). A self-determination theory approach to predicting school achievement over time: The unique role of intrinsic motivation. *Contemporary Educational Psychology*, *39(4)*, 342–358. https://doi.org/10.1016/j.cedpsych.2014.08.002

Turner, J. C., & Meyer, D. K. (2000). Studying and understanding the instructional contexts of classrooms: Using our past to forge our future. *Educational Psychologist*, *35*(2), 69–85. https://doi.org/10.1207/S15326985EP3502_2

Turner, J. C., & Patrick, H. (2008). How does motivation develop and why does it change? Reframing motivation research. *Educational Psychologist*, *43*(3), 119–131. https://doi.org/10.1080/00461520802178441

Urdan, T., & Kaplan, A. (2020). The origins, evolution, and future directions of achievement goal theory. *Contemporary Educational Psychology*, *61*, 101862. https://doi.org/10.1016/j.cedpsych.2020.101862

Additional Resources

(1) **Shumow, L. & Schmidt, J.A. (2014). *Enhancing adolescents' motivation for science: Research-based strategies for teaching male and female students*. Corwin Press.**

This practitioner book details motivational constructs with illustrative vignettes specific to science and offers research-based strategies for supporting students' motivation in secondary science classrooms. A companion website provides tools for practitioner reflection, illustrative video clips, and additional resources.

(2) **Windschitl, M., Thompson, J., & Braaten, M. (2018). *Ambitious science teaching*. Harvard Education Press.**

This practitioner book describes multiple strategies and tools for teachers to plan for students' meaningful engagement with science. While not framed specifically in terms of motivation theory, the book outlines multiple motivationally-supportive strategies that are deeply rooted in science learning, particularly around facilitating discourse about science concepts.

(3) **Guskey, T.R. (2002). Professional development and teacher change. *Teachers and Teaching: Theory and Practice, 8*, 381-391.**

This article synthesizes research on how teacher professional development translates into changes in teachers' practice and attitudes, as well as gains in student learning outcomes, identifying several challenges to designing professional development and highlighting characteristics of effective professional development.