



Deep teaching in a college STEM classroom

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Abstract

The retention of underrepresented students remains a significant challenge in the STEM (Science, Technology, Engineering and Math) disciplines. A broad range of studies across several disciplines have shown that conventional approaches to STEM instruction may have been unintentionally exclusive to students whose ethnicities are not traditionally represented in the STEM fields. This ‘exclusive’ classroom atmosphere has emerged as a major reason for the attrition of underrepresented minority students from STEM majors. In this manuscript, I describe a conceptual model called Deep Teaching, describing how pedagogical transformation incorporating practices that are more inclusive can occur. The model marks an evolution from other frameworks advancing inclusive instruction in higher education by advocating for the primacy of Freirean philosophy when thinking about self and student. Using specific examples, I discuss how a sequential approach to understanding ourselves and empathizing with students puts the instructor in a better position to create enduring, positive classroom climates. I also describe considerations necessary for various contexts, and suggestions for continued commitment to inclusive pedagogy in the long-term.

Keywords Inclusive · STEM · Pedagogy · Underrepresented students

Personal journey in STEM pedagogy

In my office, there is an enlarged picture on the wall of my first group of college classroom students. This course was taught at a large, public research university in Miami, Florida. I was their teaching assistant (TA) for an introductory ecology lab course. At this time, my institution was just beginning to think about applying progressive approaches to pedagogy as outlined in the Vision and Change report (AAAS 2011) to the biology curriculum. I taught for a specialized program within the Department of Biological Sciences called QBIC (Quantifying Biology In the Classroom; Weeks et al. 2011) that was tasked with introducing some of the pedagogical suggestions from the report. Most of the students in

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the program (98%) were from ethnicities that are federally considered to be underrepresented in STEM. The majority of that group self-identified as non-white Hispanic. As part of the ongoing pedagogical planning process, faculty associated with the program met regularly to discuss various logistical aspects of the program. During these meetings, as part of general discussion of the students, instructors and TAs from this program would often collectively complain about what they perceived as a consumerist, utilitarian approach they felt students took to learning. There was genuine surprise at the single-mindedness pre-medical students showed with respect to career choice, and in response, faculty rarely believed in the authenticity of their career aspirations. Faculty discussions of student performance focused heavily on student deficits, and the many ways in which students seemed incapable of meeting the instructor's definition of quality work. The narrow lens through which faculty judged student academic behavior precluded any consideration of other potential social impacts.

As I reflected on my experiences in the classroom when I was an undergraduate who identified as Black, I felt some empathy for the classroom experiences of my current students. I recall deep struggles trying to connect to what seemed like an arbitrary standard of what scientist vernacular and behavior should look like. In spite of this empathy, I still felt however that as their TA, I needed an even greater understanding of their unique student experience. Part of this stems from the reality that though many of the students shared the same phenotype, the ways in which they navigated identity development were likely different. Therefore, authentic listening is necessary to unpack unique social strategies. In one-on-one meetings with each individual, I had conversations about career choices and academics. I learned from those conversations their interpretation of how social forces in their lives influenced thinking on career choice and subsequently their courses. Students spoke of the intense family pressure they faced to choose specific careers due sometimes to the perceived prestige associated with them, or the potential of income mobility. There was a general unawareness of the different career pathways available if students were simply interested in science without an automatically associated trajectory. These informal conversations helped me understand that the students I taught developed their science and professional identity in nuanced ways. It was also apparent that the ways in which instructors constructed their pedagogy in ways that excluded the student voice from the process.

This experience led to a reimagining of my entire pedagogical approach with a more careful consideration of *whom* I was teaching. This reconsideration meant that I first needed to understand my own intersectional identity, and more deeply know who the students were as people, *before* thinking about ways to redevelop my curriculum. To shore up my knowledge on the student experience specific to my location, I read a number of books that helped explain the history of the social structure of Miami. Miami is a large metropolis whose political and social histories were deeply impacted by immigration patterns from South America. The city is mostly Hispanic, with much of that demographic being of Cuban descent. Recent immigration patterns from Venezuela and the Dominican Republic has affected this however. Social and political dynamics within the city has been informed by these patterns and the resident populations of African-Americans, and peoples from Afro-Caribbean diasporas. The majority of my students matriculated from this locality. One of the books that helped illuminate these relationships was T.J. English's 'Havana Nocturne' (2009) which described the social relationship between Cuba and South Florida in the days preceding and after the Fidel Castro-led revolution. I also read Michael Grunwald's (2006) exhaustive historical treatise describing man's attempt to 'tame' the Everglades in 'The Swamp'. This description was set in the context of the social and political development of south Florida. Marvin Dunn's (1997) 'Black Miami' was a fascinating

perspective of the history of the peoples of African descent who inhabited Miami since slavery. Dunn details the political struggle before and after the civil rights era in the black communities, and the ways in which the nature of those developments changed once the Caribbean and South American immigration influx occurred. In addition to learning more about the local community, I reflected on the role that my own historical biases, and privilege potentially played on the expectations I had for my students, and the degree to which those expectations may have been a product of my own relatively narrow educational experience.

I also reflected on my own education journey, from my arrival to America as an international student of color, to the homogeneity of the Historical Black College I attended as an undergraduate, and then into the majority white world of the ecological sciences as a graduate student. The nature of this pathway was informed by my own intersectionality. As a Caribbean native of African descent, I was both a foreigner to the historical experience of the disenfranchised minority, as well as an automatic member of that very group once I relocated in this country. Maria Rivera Maulucci (2013) describes in detail such an experience of a Caribbean international, expounding on the various meta levels the individual's identity development is nested in. My personal experience navigating this pathway helped me empathize uniquely with the reasons why students identified with very specific types of STEM careers. More specifically, I had personal experience with a STEM pedagogy that rarely engaged my voice or cultural backgrounds, but instead led me along with a list of pre-prescribed behaviors, textbooks, ways of thinking, and disciplinary cultural norms. In teaching these students, I saw how the cultural homogeneity within the discipline created an academic and social environment to which students struggled to connect.

In response to my reflection, I dedicated myself to learning pedagogical techniques that engaged the students in contextual learning (Forneris and Peden-McAlpine 2006), and deeper retention (Schultz 2012). I also researched strategies that utilize those techniques to build a greater sense of community in the learning process (Braxton et al. 2000). These were largely active learning approaches, informed partly by the call of multiple reports to transform that way in which science is taught in the classroom (for example AAAS 2011). I also ensured that the resulting course provided students ample opportunities to exhibit agency, and advocate for the shape of the education process they wanted to be a part of. As a result, my teaching experience was diametrically different from that point forward. The students in my class were no longer mere passive receivers of content. They were individuals, whose interests, approaches, and behaviors had a context within their personal and cultural histories. Every interaction with them, whether it was specific to the content or otherwise, focused on relationship building. It was within this context of this trusting relationship, that learning took place. In the same way they learned from my own experiences thinking about experiments in science, I learned elements about the human experience from their narratives that have continued to inform my thinking on teaching to this day.

Inclusive pedagogies in higher education

Compared to the K12 literature, frameworks of inclusive teaching in higher education are only starting to penetrate discussions of university pedagogical praxis. Depending on the context, models for inclusion range from strategies to consider more cultural relevance (Gay 2010), to new paradigms aimed at broader overhauls of the higher education ecosystem. Brittany Aronson and Judson Laughter (2016) synthesized various viewpoints of the

paradigm of ‘cultural relevance’ in particular, including praxis in STEM classrooms. Other models of inclusive pedagogies exist however. For example, Verna Kirkness and Ray Barnhardt (1991) suggest a ‘four R’ (respect, relevance, reciprocity and responsibility) model, as an antidote to the deficit framework typically used to discuss American Indian student performance in higher education. Building on that same notion of deficit thinking, Daniel Smith and David Ayers (2006) argues for the incorporation of non-westernized modes of thought as a basis for truly inclusive education. This argument in particular was in direct response to the rapid increase in international student diversity.

Another common inclusive teaching model used is Universal Design Learning (UDL; Silver et al. 1998; Rose 2000). The core principles of UDL primarily address the inclusion of students with disabilities (Pliner and Johnson 2004), but the application has been expanded to incorporate a more social justice oriented pedagogy. Some inclusive models aim at systemic change. Multicultural education models for example provide a comprehensive structure around which systems of teaching and learning can provide an equitable experience for students from diverse backgrounds (Sadker and Sadker 1985). They address various aspects of the delivery of education from the curriculum materials to the development of an appropriate campus climate to ensure that inclusive instruction has context. In his review, James Banks (1993) identifies the five dimensions of multicultural education as content integration, the knowledge construction process, prejudice reduction, equitable pedagogies, and an empowering school culture. I will not re-review these dimensions in this manuscript, but, in his delineation, Banks identifies the need to expand the concept of multicultural education beyond diversifying curricular examples. This point was further argued by identifying equity pedagogy as the basis for effective multicultural education (McGee Banks and Banks 1995).

More recently, Linda Marchesani and Maurianne Adams (1992) proposed a faculty development model that addresses the dynamics of multicultural teaching and learning. Their approach narrows the focus a bit to examine how faculty can transform classroom pedagogy. They identify four main areas of focus for the inclusively minded practitioner. These are knowledge of self, knowledge of students, content of curriculum and teaching approach (Marchesani and Adams 1992). This explicit focus of paradigm shifts in faculty mindsets also inform the conceptual model discussed here. The model I propose expands on this concept by applying Freirean thought to the relationship-building component of pedagogy. I also argue for the primacy of practitioner understanding of self and student relationships, *before* the mechanics of curriculum building and classroom instruction can begin.

Deep teaching in STEM

In this paper, I discuss a conceptual model, partly based on my personal experience and partly on a faculty development framework developed by Linda Marchesani and Maurianne Adams (1992) that can promote inclusiveness in the classroom. In this model, I emphasize the need for a sequential approach to developing an inclusive classroom. The model focuses on STEM classrooms as the challenges with retaining students, especially underrepresented minorities (URMs) in this area, continues to warrant special focus on the pedagogy (Hurtado et al. 2010). A recent report on student attrition from STEM majors has shown that nationally, 53% of underrepresented minorities declaring a STEM major end up leaving the institution without a degree in any major (Chen et al. 2013). This is more than

double the percentage of white students (20%) who undergo the same fate. Other studies have shown that the alienating climate of STEM classrooms can play a major role in this attrition [Seymour and Hewitt 1997; Soldner et al. 2012 but see Brown et al. (2015)]. Using specific examples, I will discuss the role that well-designed pedagogies can potentially play in creating a more inclusive experience for all students. I will also discuss the literature that provides the evidence for the ways in which the various model components affect academic outcomes, and practical interventions for practitioners to consider. I emphasize however that while the practical suggestions are important, true classroom transformation can only occur with a long-term commitment to the instructor's personal reform. The foundational competencies (self-awareness and empathy) are typically not successful as bite-sized implementations (Dobie 2007). For this reason, I describe the first competency (self-awareness) as superseding all others, and extending beyond them. The implication here is that a full self-understanding and how we situate within a dynamic society is an ongoing, never-ending process. Recommendations made here are not meant to be a comprehensive review of all interventions in each area of pedagogy, but can serve as examples of strategies instructors can adapt for their own contexts.

I view the discussion on inclusive teaching as a natural evolution in the ways that the improving practice of college teaching (especially in STEM classes) is discussed. An inclusive classroom is one where all voices, regardless of background have equal opportunity to contribute to and shape the community dialogue. This has implications for the pedagogical approach. Conventional, content-driven approaches predicated on the question 'what do you want students to know?' (Diez and Moon 1992). The active learning reform movement asked us to figure out 'the skills we wanted students to develop' (Biggs 1999). Here, I am asking the reader to ponder 'who do we want students to be?'. In this vein, I consider the instructor not to be teaching *science*, but teaching *students* (Moje 1996). Teaching 'science' places the focus on the delivery of subject matter, and all of the nuances associated with its retention and understanding. While this is important, reducing the educational experience to the cognitive domain shortchanges the transformational potential it of the process. In teaching 'students' we are forced in Freirean (1971) philosophy to engage the totality of the body (Darder 2011) in the experience. We are asked therefore to think of the relationships created and to contextualize the exchange of information within the framework of that relationship. This paradigm makes teaching inclusive. It implicates *the instructor* as part but not necessarily central to the learning process, and ascribes greater power to the student voice. Hagar Ibrahim Labouta, Jennifer Adams and David Cramb (2018) model this relationship-driven pedagogy in their description of the Integrative Cultural model. The ICM is centered on the strategies students use to leverage classroom relationships that may help them develop a positive science identity. This includes the relationship with the instructor, and the sense of otherness that they may bring to the classroom. Therefore, like any fruitful relationship, we are required to have an understanding not just of those with whom we are engaging, but also of ourselves, and all of what we bring to the table. This bears similarity to the ways in which we challenge our students to move beyond the superficial to become deep learners (Case and Marshall 2004). Deep learning is thought to have uniquely analytical and interpretive components (Mayhew et al. 2012). It also is considerate of the existing knowledge schema of the individual. In the same way, 'Deep teaching' therefore extends beyond the superficial delivery of content knowledge, moves beyond inclusion and toward engaging the social contexts of the students. I therefore define Deep teaching as the constant, critical reflection practitioners apply to their awareness of self and student, as well as the degree to which this reflection informs the practice of an equitable pedagogy. This is not an entirely new paradigm. Freire (1968) argued for moving away from the 'banking'

of information toward a dialoguing approach where the social realities of the students are fully engaged. His later works elaborate on the artificial separation between emotion and intellectual pursuit that is indoctrinated into the academy (Freire 1993). Far from being simple purveyors of facts John Dewey called on educators to engage a pedagogy of liberation, where leveraging the classroom community can lead to citizens who hold society accountable and work toward social equity (Dewey and Boydston 1984). Deep teaching asks of us to revisit our classroom practices to think more critically about our long-term goals for our students and ourselves. It is not a narrow pedagogy that focuses solely on uplifting the disenfranchised. It forces a fresh examination at the unintentional hierarchical structures created by conventional approaches, and the ways in which broader social inequities replicate themselves in the classrooms when *laissez faire* strategies are employed. The model discussed here frames this thinking. I also provide specific suggestions for how it applies to a STEM classroom.

The deep teaching model

The Deep Teaching model comprises five key competencies (Fig. 1). The components bear some similarity to those found in Marchesani and Adams (1992) model for teaching to promote social justice. In their model, the authors emphasize the complex interplay, in a four-quadrant model, that typically occurs between knowing oneself, knowing one's students, the development of curricular materials and establishing a classroom climate. In the Deep Teaching model, I explicitly incorporate the potential additive potential of leveraging on-campus networks and I emphasize the need for a sequential approach to the model's adjudication. The components of Deep Teaching are—(1) *Self-awareness*, (2) *Empathy*, (3) *Classroom Climate*, (4) *Pedagogy*, and (5) *Network leverage*. The model begins with self-awareness as it is important for instructors to understand themselves before they engage with other aspects of inclusive classroom development. Below, I define each component, and more broadly explain their conceptual bases and implementation.

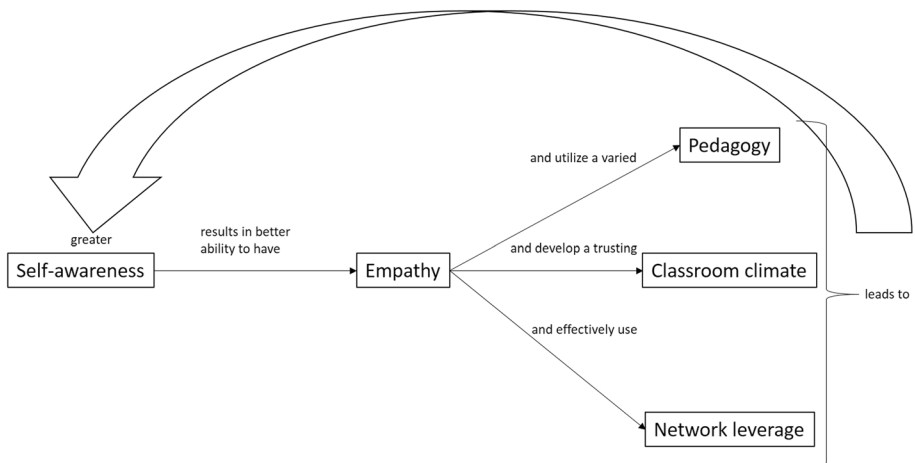


Fig. 1 Whole classroom model

Self-awareness is the degree to which the instructor has an understanding of him or herself in the context of what they bring to the classroom. This requires a preparedness that goes beyond content knowledge. The social positioning of the instructor is a function of their individual histories, and the ways in which those histories informed their development of a science identity. A pedagogy predicated on relationships requires an understanding of self before one can fully engage students.

Empathy in the context of this model, is defined as the degree to which the instructor commiserates with the social context and authentically listens to the voices of their students. An instructor would have to be purposeful in the degree to which they gather location-specific information about the students they teach, and their engagement in understanding the literature on how their students navigate the academic environment.

Classroom climate refers to the general temperament created in the course as a function of a number of factors including the physical layout of the classroom, the nature of the verbal interaction with students, and the structure of the interactions between the students.

Pedagogy broadly refers to the approaches used to maximize deep learning and retention of academic material. In this context, it focuses on content, and how mastery of course-related skills are enhanced by evidenced based strategies informed by the relationships within the community.

Network leverage refers to the use of a variety of campus support structures to enhance the facilitation of student success within the classroom. These support mechanisms typically exist on most college campuses, but within the organizational structure they are often siloed under student affairs. In this model, we discuss ways to more explicitly develop classroom relationships with these offices, and incorporate their message of inclusion within the classroom pedagogy.

Self-awareness

The ethnic diversity of college students will increase substantially in the upcoming decades (Prescott and Bransberger 2008). Non-white ethnicities are projected to occupy the majority of college classroom seats by the year 2050. On campuses where ethnic minority populations have been historically low, faculty, staff and administrators may not have formative experience considering diverse experiences of students as part of their practice. The increasing numerical diversity has forced faculty and administrators to reflect on the current culture of the higher education system. Culture in this context refers to the total interactions between administrators, faculty and students that are geared toward the students' academic and social development. Institutions that are accustomed to a student and staff population containing individuals from dominant cultures, may reflect in their instruction and interactions dominant culture assumptions. In deconstructing this culture, administrators must consider the degree to which instructors understand how the lack of formative experience with diversity might impact their interactions with students (Feagin 1992; Sidelinger et al. 2016). A potential outcome of this lack of experience is the harboring and accretion of implicit biases. These biases reflect how individuals unintentionally internalize broader social constructs and norms (Blair 2001). For example, an instructor may enter a classroom and, without realizing it, react to the students based on internalized opinions concerning their ability based on race, gender, personality type or other social identities. There are physiological and psychological reasons that help explain how biases develop (Rudman 2004). Haidt (2001) for example explained, that we are more likely to use reason after a given incident to explain an emotional reaction that we may have had to

the experience. In the context of how we judge people (students), our perception of them is likely affected by previously held biases relating to their identity. We may not even recognize the development of those biases (hence implicit), or may explain away our perceptions using language like ‘underprepared’ or ‘different population’. The biological basis for bias development however does not absolve individuals from taking responsibility for it. Freire (1993) postulated that we shape the world as it shapes us. This umbilical connection to social otherness can be more explicitly incorporated into teaching. In this way, our instruction and interaction with students is not artificially divorced from the reshaping process (Freire and Shor 1987). Freire’s views liberation diverge from conventional views of other as a move away from default objectification that typifies many human relationships (Freire 1961). In the conventional model, the ‘owner’ not only views of the other as a possession, but feels identity-threatened if a circumstance were to arise that would negatively affect that ownership (Lake and Dagostino 2013). Similarly, an instructor’s interpretation of their relationship with their students can be indicative of their willingness to allow students to fully actualize within the experience. There is a fear on the part of college instructors to allow this relationship to transcend intellectualism and migrate toward the emotional, due to the perceived loss of associated classroom control. However, the processing of the intellectual aspects of knowledge goes hand and hand with the emotional, and this totality should be conveyed in our classroom pedagogy.

What does it then mean to ‘recognize’ implicit behaviors? A strong body of evidence now exists to support the fact that implicit biases do color daily decisions in all of our lives (Dovidio et al. 2002), but for this recognition to be meaningful, it must be further unpacked. Social positioning is a consequence of individual intentions and the social structure within which they navigate. The ability to access and utilize resources broadly is influenced by the ‘life situation’ into which the individual is born. Even a cursory reading of social history demonstrates that not all groups in multicultural America had the same access to resources through time, or were viewed as having the cognitive capabilities to efficiently use them (Selden 1999). In extreme cases, some groups were actively disbarred from accessing those resources (Massey and Denton 1989). Therefore, phenotypic characteristics inherited at birth bred powerful social preconceptions, and were subsequently extraordinarily predictive of the degree of resource access. Phenotype thus acted as a social strainer, providing access to particular opportunities only to those positioned, purely through chance at birth, to access it. Studies on social privilege show that many individuals are not only unaware that they were the beneficiary of unearned social advantages they possessed, but also the degree to which institutional structures allowed them to perpetuate and accrue these advantages further (Case et al. 2012). In this context, benefits of privilege do not simply accrue based on race, but also due to any characteristic whose inherent stratification allowed specific categories of people to benefit at the expense of others. Antonia Darder (2011) views this, in her interpretation of Freirean thought, as an unfortunate but deterministic outcome of capitalist systems. The mere possession of privilege therefore is not itself problematic, but the myopia or obliviousness displayed by individuals who possess it can create issues, especially if those individuals are obligated to serve diverse populations of students. In the classroom, this myopia can manifest itself in the assumptions instructors have about their students and abilities, the narrow cultural paradigms reflected in STEM instruction, and the resistance to engage the social realities students bring to the classroom.

The Implicit Association Test (Greenwald et al. 1998) or the Privilege Walk (Sassi and Thomas 2008) may help instructors become aware of the ways their chance-at-birth positioned them for advantage or disadvantage, but a fuller understanding of the manifestations of that inequity demands a deeper engagement with the literature and themselves. The

instructor's understanding of how unequal patterns of assimilation come to inform social positioning is useful to gain a better perspective of themselves as well as their students. This requires reading outside STEM scholarship. For this journey, literature on cultural assimilation (Neidert and Farley 1985, Abramitzky et al. 2016), the pervasiveness of racism and racist ideas (Feagin 2014), and privilege in American society (Ullucci 2006) can be particularly helpful. The education provided by these readings will allow the instructor to reflect differently on their position as a major stakeholder in the academic and social outcomes of their students.

As a black male of Caribbean descent, teaching in a university located in the New England region of the United States forces a unique self-awareness. As an immigrant, I am constantly trying to better understand the fullness of the American experience. As a faculty member of color, I am acutely aware of biases toward me brought on by my phenotype. I am also mindful of the biases that I may possess, especially towards identities with which I do not have deep experiences. To this end, I take the IAT before every academic year for various categories, reflect on the results, and determine the self-growth that I need to address my biases. Reflection also entails revisiting the historical and contemporary drivers of my pedagogy (Dewsbury 2018). This self-awareness is a never-ending journey, since social evolution and the constant influx of new students should continue to inform our self-awareness. An increase in self-awareness better positions instructors to develop empathy for their students.

Empathy

Most productive social relationships require some degree of understanding from each stakeholder in the relationship of the social context that inform people's behaviors (Sulzer and Burglass 1968, Leary and Baumeister 2017). Similarly, building effective relationships with students require a clear understanding of their broad histories, and how those histories and potential identity contingencies (Hurtado et al. 1998, McGrath and Van Bergen 2015) helped shape their approach to learning in higher education. Empathy, as defined in the literature with respect to pedagogy refers to the extent to which instructors understand the student experience (McAllister and Irvine 2002). The empathetic instructor typically engages in quality out of the classroom communication and displays a degree of intentionality in trying to know their students more deeply. This type of personal engagement however can be challenging in situations where instructors have high enrollment college courses. In those scenarios, it is impractical to expect instructors to develop deep personal relationships with each student. There may be however, other mechanisms to relationship building in these situations. Empathy for the students' authentic lived experiences can be reflected in the ways the voices of their social contexts are incorporated into instruction (Barton 2001). Empathetic STEM instruction embraces and negotiates the fuzzy borders between science practice and everyday experiences (Barton 1998), engaging the full body of emotion of the student (Darder 2011).

Empathy toward students has a macro and a micro level. On a macro level, it is important to understand the historical and social contexts that inform the students' presence in the classroom. Much of this information can be gleaned from the same areas that inform the ways in which we understand ourselves in a cultural context. Indeed, the first two steps of the Deep Teaching model asks the instructor to intentionally deconstruct the social context of the instructor-student relationship, and points to areas of literature that would be applicable here as well. In the absence of this knowledge, it is conceivable to see why

conventional teaching might focus purely on content delivery, with no consideration of the social schema students bring to the classroom. In addition to understanding broader social structures, instructors will be better positioned to develop empathy of their students if they are aware of the social conditions that are specific to the immediate social environment of their students. For example, in cases where universities attract in-state students, the politics and social structure of the communities within will inform to a degree the ways in which the students engage the campus. Primarily commuting students bring a significantly different affect to a classroom when compared to on-campus residential students. Depending on their living situation, their non-campus social concerns may be impacted by relationships with family, connections within their home community and/or demands of employment (Kuh et al. 2001). Returning adults and military veterans bring a unique dynamic to the classroom typically not present in recently high school-graduated college freshmen. Luis Moll et al. (1992) terms the social assets students bring to the classroom as 'funds of knowledge'. This non-deficit approach restructures the framework around the student from a problem to be fixed to potential to be leveraged. A deep pedagogy cannot engage all social scenarios in the same way. There is some evidence from the psychology literature pointing to unique contingencies that might arise in college classrooms as a consequence of diverse classrooms. Stereotype threat (Steele 1997), and low sense of belonging (Hoffman et al. 2002), are examples of psychological phenomena that arise from a student's acute awareness of both personal identity, and the perceptions of that identity by others. In stereotype threat, hyper awareness of negative perceptions can affect academic performance. Low sense of belonging can lead to a departure from the discipline due to the perceived reinforcement of the view that their identity has predisposed them to failure (Hausmann et al. 2007). An instructor who fully understands how these phenomena work and how their negative effects can be mitigated can design a course that incorporates those strategies.

On a micro level, many students are encouraged to persist when the instructor personally validates their efforts (Rendon 1994, Cleveland et al. 2017). Instructors with low-enrollment classrooms may have the luxury to learn names and possibly other intimate details about their students, and certainly should maximize that opportunity. Instructors at large universities often teach introductory classes in the hundreds, where that level of personalization is difficult. As student debt concerns (Burdman 2005) and the increased closure of private institutions mount (Bates and Santerre 2000), more attention will be placed on institutions that are able to scale effective pedagogy to large classrooms. In these large classrooms, a few tools are available to personalize the experience for the student more. The Learning Assistant (LA) model facilitates peer instruction, aids in the implementation of active learning, and helps 'shrink' the class to the size of the group being supervised by the LA (Otero et al. 2010). For students with identity contingencies and introverts, small-group work can reduce the sometimes crippling effect of large classrooms (Bonwell and Sutherland 1996, Murphy et al. 2017). The use of analytical courseware can aid instructors to quickly assess learning before summative assessments, focus interventions on specific students, and determine the specific nature of student struggles where applicable (Arnold and Pistilli 2012). An instructor can devote their assistance time to students who are struggling academically, and, depending on how course data is gathered, dialogue with the student about very specific aspects of their struggle.

Developing empathy for my students begins for me with processes that occur before the semester begins that help me get to know them more as people. I work closely with our institutional research office who provides me with demographic data of the students entering my classroom. This data set gives me a sense of the experiences students bring

into the classroom from their high schools, or other universities. It also gives me a sense of the racial and gender breakdown of the incoming community, alerting me to the potential of the development of identity-related contingencies. Additionally, I send students a short survey asking for their prediction of performance in the course, history doing science (any subject), and their feelings on group work. This means that before I see the students, I have a loose sense of their academic histories, and other ways in which they engaged in the STEM learning process. On the first day of the course, I ask them to write a reflective essay with the prompt 'I believe' (<https://thisibelieve.org/>). This assignment, shared only between student and myself, asks the students to look into their soul and articulate the things in their lived experiences that are most important to them, and their role in determining their futures. This assignment is the most powerful of the information gathering process and is what chiefly informs the dialoguing relationship. I read all of the student reflections, and ensure that the dialoguing in the course reinforces their personal desires to generate social impact.

The instructor student relationship is a critical aspect of the education process. If STEM instruction intends to move away from 'banking' into students toward 'dialoguing' with them, the voices of students will be key to reframing the parameters of the community. Morales-Doyle (2017) highlights the importance of the student voice in the development of justice-centered science pedagogy. Creating the space for these voices to contribute to a dialogic curriculum is therefore key to building an empathic relationship. Within this relationship, the instructor can develop a classroom climate and pedagogy that promotes effective learning.

Classroom climate

Classroom climate as a term, is extensively defined in K12 classrooms (Walberg and Anderson 1968). Belonging in the classroom is predicated on the notion that student success in the course is a shared responsibility between all students and the instructor (McMillan and Chavis 1986). There are many reasons why the creation of a positive classroom climate is important for the sense of belonging and the learning process. The nature of the interaction between faculty and student, and the degree to which a student can feel that they are a part of a shared positive experience might be the single greatest intervention available for identity contingencies (Cohen and Garcia 2008). The literature has provided multiple frameworks to consider when we engage with students, all of which depend on an a priori understanding of ourselves and possessing empathy toward the students. Vygotsky (1978) sociocultural theory for example has recently been used to demonstrate a bit more clearly how successful learning can take place in the college context. According to this theory, the creation of the appropriate learning environment is key before curricula is developed. This learning environment should be designed within what is referred to as the Zone of Proximal Development (Vygotsky 1978). While this theoretical framework has mostly informed curriculum in early childhood education (Siraj-Blatchford 2009) and second language development (Lantolf et al. 2015), recent studies have highlighted its role in the development of postsecondary constructivist pedagogies (Hall 2007; Wang 2007). For example, pedagogical approaches such as problem-based learning (PBL) rely on the quality and development of the sociocultural interactions that define the teams (Hall 2007), which then substantially inform the success of the PBL approach in the classroom.

Promoting a positive classroom climate can go a long way in creating the culturally appropriate environment and engagement necessary for future learning. Engagement in

this context includes the language and tone used to address students and provide feedback (Brinko 1993; Brookhart 2017), our ability to decode and respond to body language from students, the ways in which we monitor interactions between students, and the extent to which we help students develop the skills associated with positive collaboration. Developing an inclusive classroom thus considers diversity of all types. It is the fine-tuning of one's social radar to be cognizant of ethnicity, personality type, gender, and other salient characteristics that comprise diverse classrooms. Part of developing this inclusive classroom climate involves validating the identities of those in the classroom. Therefore, once all stakeholders feel a sense of belonging, and buy into the concept of the community, the class can become a place of trust. For STEM instructors seeking to 'activate' their classrooms, the concept of classroom climate can be a nebulous one. It lacks the precise measurability demanded by most active learning approaches and does not come as a pre-packaged, universally deliverable instruction tool. The notion of being socially hyper-aware of dozens of unique students speaks to a skill set rarely broached in pedagogical training at any level. In addition, few STEM faculty were provided spaces to explicitly consider this during graduate training. However, when thoughtfully implemented, it can catalyze the successful implementation of active learning strategies (Dewsbury 2017). For example, clicker use is a wonderful formative assessment tool, but, if the tone of the feedback is condescending or reinforces fixed mindsets, potential benefits for the student are essentially nullified. There is a lot of evidence for the potency of small group work in STEM classrooms, but the power of this approach lies in the nature of the interaction within the group, not simply from its existence. Active learning meets inclusive teaching where the instructor critically engages dialogue and considers context (Dewsbury 2017). The nature of the feedback is mindful of the individual receiving the feedback, and the ways in which instructor language and verbiage can encourage the student or unintentionally reinforce dominant narratives. Small group work can be unleashed as a pedagogical tool to develop skills in working with diverse teams, collaboration and problem solving. But, like any social situation, the ways in which instructors engage individuals is a function of both their history doing so and also their comfort level. At times, active learning can be perceived as the domain of extraverts (Reilly 2000), where instructors are encouraged to develop an almost salesman-like mentality for their instruction style. In Deep Teaching, the focus is on the nature and quality of the dialogue, and not the appearance of energetic interactions or incorporation of game-like tools. Instructors therefore need not feel pressured to 'perform', and instead should place a clear focus on the ways in which they validate students' identities, encourage growth mindset and provide opportunities for students to engage their social realities in the classroom.

Like many STEM faculty, I was not formally trained in the artistic dimension of teaching and therefore need to continually learn the physically demonstrable dynamics necessary to help build trust. There is a deep history of the role that instructor non-verbal cues play in setting classroom tone (see Neill 2017). Some of these cues can possibly improve my classroom climate. To this end, I meet frequently with a colleague who is a Professor of Theatre. Her suggestions of breathing exercises, intonation perfection and loose body language, go a long way in helping me craft the communal affect I deem appropriate for the classroom experience. From a visual perspective, I learn a lot about myself and the art of communication by closely following radio and television interviewers, stand-up comedians and improvisational theatre. These skills come to bear when I am discussing concepts with the whole classroom or when I am meeting with students individually. During the semester, I use self-deprecating humor to humanize myself and carefully monitor visual responses to

determine the level of engagement. Changes in facial expressions and body language of the students serve as physical indicators of tiredness, interest, enjoyment and motivation, all of which inform the subsequent activities I use to maintain a trusting climate.

Pedagogy

In recent years, a greater focus has been placed on using evidence-based pedagogical practices (in STEM teaching especially) as the nation continues to find ways to reduce the attrition of underrepresented minorities from STEM majors (Allen-Ramdial and Campbell 2014). Some of these evidence-based practices appear to positively affect historically URM students (Freeman et al. 2014). Therefore, engaging in the contemporary teaching practices that improve teaching and learning is a critically important component of inclusive teaching. Contemporary approaches to pedagogy matter to inclusiveness in that the continuous feedback and assessment of student progress encouraged by active pedagogy are central to their effectiveness (Black et al. 2004). These approaches provide instructors better opportunities to maintain a sense of how at-risk students may be faring in the course. This is an inclusive practice in that it does not place the burden of responsibility entirely on the student, and is cognizant of the situational factors that may affect their ability to keep pace with the course. In general, contemporary pedagogical approaches shift the focus of the classroom from instructor-centered to student-centered, where the ability of the students to achieve clearly constructed learning outcomes is the explicit focus of the classroom experience.

Though the evidence supports the use of active techniques in the classroom, determining clear boundaries for what constitutes active learning is surprisingly difficult (Keyser 2000). An instructor interrupting their lecture with a single clicker question can officially be classified as active similarly to others who completely flip their classroom. Research into active learning is still attempting to clearly identify the specific aspects of this approach that promotes learning, and the contexts in which it is more effective (but see Eddy and Hogan 2014). For the ‘deep’ instructor, the focus should be almost exclusively on the student. Active learning strategies applied without context risk being ineffective or even worsening the learning experience. To reiterate our guiding question and applying it to a backward design process one should ask—‘who do we want students to be?’. This vernacular forces the instructor to think beyond the content of the course, and consider skills that can be developed within the social framework of the class to meet this goal. For example, if we are interested in students applying the principles of good teamwork in solving scientific problems in their future practice, what specific things can we do in the classroom today to model and assess that? If we want to students to engage future diverse colleagues, leveraging their different life experiences to grow intellectually and socially, what opportunities can the classroom provide to support that process? What are we doing in our instruction to leverage *their* unique experiences (Mensah 2011)? Bishop (2008) refers to the leveraging of these experiences as agentic positioning. It dovetails with the Freirean paradigm of pedagogy as the extraction of knowledge that is already within (Freire 1974, p 76). Science instruction is a more powerful experience if the inquiry process is directly connected to the students’ personal experience (Mensah 2009). If we are interested in attracting more diverse students into STEM disciplines, how are we representing these disciplines culturally to students in our classrooms by way of textbook examples, historical references, or the ways we engage discussion of historical ethical conundrums (Kohli and Solórzano 2012)?

A liberation pedagogy is fundamentally based on the power of the instructor-student dialogue, in that both actors are party to shaping the classroom curriculum. Learning outcomes should be constructed to reflect that. Operationally, this is very challenging. Westernized ideologies of Nature of Science (NOS) govern the structure of higher education STEM content, even when progressive pedagogies are employed. Incorporating decolonized STEM pedagogies requires a monumental paradigm shift that transcends the limitations of westernized ways of knowing. Smith (2013) provides some useful advice for how decolonized science can be imagined with respect to indigenous peoples. Similarly, STEM curriculum design that is inclusive of the student voice means being both open to listening to that voice, and being able to incorporate the message into the classroom structure. Nouri and Sajjadi (2014) offer a useful model for engaging in emancipatory pedagogy, and Convertino (2016) demonstrates how this paradigm is useful in training preservice teachers. In STEM classrooms, Morales-Doyle (2017) and Emdin (2010) delineate the democratization of their classrooms by listening to the critique and the expressed perceptions of their students. STEM classrooms in higher education is sorely lacking in such examples.

In my classroom I provide many opportunities for students to show agency toward how the educational experience is shaped. I do not label my pedagogical style using conventional descriptors such as ‘flipped’ (Bishop and Verleger 2013) or ‘blended’ (Marsh 2003). The inclusive classroom experience revolves around learning outcomes that are crafted around the specific students that semester. This means that multiple modalities are leveraged to ensure those learning outcomes are met. Technology has afforded me the luxury of being able to assess within-class learning, detecting struggling students and identify the aspect of students’ academic experience they struggle with the most. In this web-enhanced approach, I employ many aspects of different forms of active learning. The full suite of methods I use in my introductory biology course is beyond the scope of this manuscript, but I point to a few opportunities I provide for students to exhibit agency. I utilize an *aggressive early intervention* approach as a primary pedagogical tool that allows students to feel continuously included in the course. Here, I assume that the reasons associated with early student struggles have little to do with capability, and are more likely connected to the difficulties of transition to college. The earlier I am able to detect these difficulties and address them in a supportive way, and provide specific strategies for improvement, the more likely I will witness a change in the student’s academic mindset. Second, I work directly with the Office of Institutional Research to access academic and socioeconomic data about my incoming students. I supplement this with a survey I send to students before I physically see them in the classroom. This allows me to get a sense of their academic and ethnic profiles, which in turn alerts me to potential contingencies they may feel pertaining to identity and abilities to perform. Third, I provide students multiple opportunities to articulate their sense of self, and the future for which they would like to advocate. On the first day of class, they write a reflection assignment called ‘This I believe’ adapted from the similarly titled NPR program. I then ensure that the learning activities in the course reflect and enhance these beliefs. For example, a student reflecting on a desire to live a life promoting social justice will benefit from learning how disciplined approaches to analyzing biological phenomena improve their abilities to address social issues.

Deep pedagogy also provides opportunities for students to dialogue with each other. For example, small group work is a major part of most active classrooms. Groups can be intentionally formed (as opposed to student self-selection), and given robust, meaningful assignments that provide students the opportunity to engage with diverse classmates. There are specific social skills and structures necessary for effective small groups which themselves can be learning outcomes (Cohen 1994). In other words, instead of simply forming groups

and assuming that the benefits of working in groups will organically emerge, the development of these skills should be explicitly stated.

In a similarly explicit manner, instructors should take a critical look at the cultural material of their curriculum. The lack of ethnic diversity in science content examples sends subtle yet powerful messages to students on 'who gets to do science'. The current lack of minority representation among STEM faculty (Nelson and Rogers 2003), and in the student population of many STEM classrooms, and curriculum material that reinforces dominant culture narratives can also further reduce students' sense of belonging. Simple strategies such as incorporating the voices of real scientists from minoritized identities may go a long way in addressing this (Dewsbury et al. 2013). An inclusive curriculum is one where both the contributions of a diverse suite of scientists are clearly identified, and also where the intersection of scientific practice with society is highlighted. Notably, there are many points in history where scientific practice and thought perpetuated the further disenfranchisement of the marginalized (Lewontin 1993). Just within the past century, the cases of Henrietta Lacks' cells (Truog et al. 2012) and the Tuskegee Study (Thomas and Quinn 1991) provide examples where social positioning dictated the relationship that different demographic groups had with the scientific research process. Thankfully, such extreme cases largely do not exist, but teaching science content in context of this nuanced history provides students a framework with which to think of contemporary technologies that have the potential to be ethically troubling (for e.g. the implementation of CRISPR). The contextualization aspect of inclusive teaching disabuses the implicit assumptions some students may have concerning the supposedly amorality of science. It replaces the delivery of content with the scientific story placed within the context of an imperfect society, and provides the students an opportunity to situate this story within their own evolving experience.

My classroom experience however is only one aspect of other components of the campus system built to create greater inclusion. Leveraging the components of this network can complement and enhance the inclusive experience of the classroom.

Network leverage

The nature of the transformation needed to transition a conventionally modeled pedagogy to deep teaching not only requires a deep rethinking of the instructor-student relationship. It demands a rethinking of the entire composition of the STEM student college experience. The development of inclusive climates can be stymied if the focus is solely on the classroom. The underlying question here is 'what is the purpose of the college experience for a student'? By most accounts, the undergraduate experience is supposed to develop both the academic and social potential of the evolving student. These categories are not mutually exclusive. They are equally important in shaping the critically conscious individual. Current campus organizational structures create an artificial dividing line between these developmental pathways by placing training models under separate branches, typically named academic and student affairs. In so doing, the development of social capital is outsourced to multicultural centers, career services, women's centers and offices of this nature. The development of academic capital without social consciousness and context is exclusive pedagogy. It denies students the opportunity to both understand how education is liberating, and ways in which understanding of themselves and diverse others can enhance the ways in which they can be socially impactful. In developing their pedagogy, instructors can and should leverage existing resources on campus that can enhance and support inclusive curricula. Traditional college campuses typically have a number of services in place to

support various aspects of student life. These services include extracurricular, leadership development, diverse social experiences to promote a more circumspect worldview, support services for those needing physical or academic support, and intervention services that help students navigate various types of obstacles (Abrams and Jernigan 1984). The implicit assumption with the conventional ways these services are made available imply that students needing these services can easily self-navigate to the office that can specifically address their need. While it is important for students to develop this ability as a general life skill, assuming that all students come into college with that degree of social awareness may be incorrect (Hinderlie and Kenny 2002). If these services are set up and offered as separate entities, then students will view them in that light. It is up to the institution to create an organizational structure that highlights the ways in which these services can synchronously promote inclusion and enhance the classroom experience. An inclusive curriculum can creatively and more clearly connect these services to the classroom. For this to take place, an instructor should be familiar with what these services offer specific to their campus. Lack of familiarity can lead to mindless outsourcing of the challenges that students face. My suggestion here is not that instructors should shoulder the responsibility of addressing all of their students' issues. However, being familiar with a network of faculty and staff who can support a student in different ways, goes a long way in ensuring that issues are not only efficiently dealt with, but that the student sees and feels a visible community around them.

Broader campus efforts on enhancing sense of community can be connected to classrooms in a number of ways. I will not detail all of them, but a few poignant examples illustrate the power of leveraging. Freshman Year Experience (FYE) courses have been shown to be very beneficial for students entering college (Purdie and Rosser 2011). Careful planning may allow departments to be more strategic with FYE instruction. For example, instead of simply teaching what good study skills are, instructors can use examples from the students' STEM classrooms to explain how to engage concepts for deep learning. Discussions on studying can also discuss the nature of both effective and ineffective study strategies, with a special focus on some of the maladaptive strategies that at-risk students sometimes utilize in response to social pressures.

Some campuses invest heavily in residential communities. An example of this are Living Learning Communities (LLCs), which are residentially based student groups centered around an academic or social theme (Pike 1999). Some LLC models focus their programming on attributes to enhance the students' social experience while others more explicitly link activities to the classroom. Many studies have shown this 'linked' model to be especially effective at improving students' sense of belonging (Inkelas et al. 2007). Instructors can also consider inviting staff professionals from service offices (for example career services) to their classrooms, who can best explain how the services they offer help the student build academic and social capital during their time at the institution. Technology can play a major role in creating this linkage. Some early intervention software can help create these linkages digitally. Efficient early intervention mechanisms are created by mapping the academic network of the student digitally (Faulconer et al. 2013). If the student encounters challenges in any aspect of their college experience, an 'alert' can be sent out to members of the network where the relevant advisor can intervene. This achieves two things. It provides a more systematic way of addressing student concerns as opposed to simply directing the student to a particular office. Secondly, it creates for the student a visible network of support whom they know are supportive of their overall progress at the institution.

I create an additional connection by inviting personnel from service offices to visit my introductory biology classroom. In this series I call 'Beyond Bio', a representative from the Multicultural Students Services Center for example speaks for about 5–8 min about the

services their offices offer, and the ways in which those services complement their introductory biology experience. Making this connection explicit helps students not to envision these services as silos, and incorporates the classroom experience as an integral part of the campus' inclusive network.

Pathways to deep teaching

My hope is that STEM practitioners draw inspiration from this model to transform their pedagogy toward deep teaching. It is likely, that most are already implementing or attempting to practice various aspects of this model. The model however provides a template for a specific sequential mechanism to implement its components.

Before a given semester begins, instructors should spend time knowing themselves. This involves reflecting on one's own pathways developing an identity as a scientist, one's implicit assumptions about the classroom, and how those attributes potentially impact the practitioner-student relationship. One should also be familiar with ways to reduce the potential that implicit assumptions manifest into negative outcomes for students. For continuing practitioners, this reflection necessarily involves previous iterations of the teaching experience, and ways in which we can learn from our imperfections as well as enhance successes. Practitioners then should seek to know their students. This involves understanding the same psychologies that may impact us, but also the more immediate social schema incoming students bring with them. Consider collaborating with the Office of Institutional Research and/or sending out mini surveys before the semester begins, such that the relationship building before any physical interaction occurs. Knowing in advance the generational status, academic background, and lived experiences of the incoming students is crucial to fostering an authentic practitioner-student relationship.

At this point of knowledge, the instructor can carefully design learning outcomes that are specific to the future classroom experience of the unique, matriculating community. Tanner (2013) provides carefully vetted strategies that an instructor can consider to promote inclusion in the classroom. The choices made by the instructor will depend on the nature of the classroom climate they wish to construct, and the strategies that best meet the learning outcomes that are chosen. Lastly, deep teaching should not exhaust the practitioner, or excessively deplete them further of limited time. Campus resources are usually available to promote inclusion, and can be extraordinarily effective if appropriately leveraged. Collaborating with these stakeholders can help build a network of support around the student, and demonstrate to them the inexplicable relationship between their academic and social maturation.

Some final thoughts on inclusion

The development of inclusive classrooms requires a framework that provides guidance on specific approaches and behaviors instructors should consider both inside and outside the classroom. In the model proposed here, I not only stress the importance of fully engaging in each competency, but also understanding the necessity of a sequential approach to the development of inclusive practices. Self-awareness as described here is not a finite process. Certainly, as the instructor becomes more self-aware, understanding the psychologies of students and developing inclusive classrooms may become easier. Cultural competency however is a skill that does not possess a true endpoint. It is nearly impossible to fully

understand the entire cultural experience of those dissimilar to ourselves. In a similar way, truly understanding ourselves and our journeys in the context of evolving social structures will require constant self-recalibration. My personal journey to inclusive pedagogies were informed by very specific experiences I had that has since informed the nature of the dialogue I engage in each semester, and my own intersectional history navigating STEM in higher education. Since the dialogue is specific to my students, no two courses or even semesters of the same course are identical. Similarly, instructors should not expect that some of the specific strategies I use at promoting inclusion are immediately transferable. It is important for the instructor to determine the strategies that are useful for their own contexts. A personal reflection of pedagogy should also consider the reality that historically, science was sometimes an instrument of marginalization and party to the reinforcement of narratives that maintained dominant power structures. How then can contemporary science instruction reconcile its past sins, and connect more intentionally with diverse students? Instructors should seek a comprehensive understanding of their student population, including the social context that informs their presence in the classroom. These include the potential identity contingencies that can be present as a function of the classroom or university's social environment. This space is where an instructor can develop the assignments, activities, interactions, and relationships would promote inclusion within the classroom. A *laissez-faire* pedagogy, with no regard for the stakeholders will simply replicate all of the social inequities that exist outside the classroom. The sequence is also important because the application of inclusive classroom tools without context or personal change and growth can promote a checklist approach, where the focus becomes only doing specific prescribed things. With personal growth comes the desire and continuous effort to seek ways to better understand the self and the students and the developing of mechanisms to maintain and enhance sense of classroom inclusiveness. It would not be possible to fully implement all that has been advised here in one semester to its full effectiveness. There are lessons learned from each iteration that can enhance our self-awareness in unique ways. Lessons learned from each semester can inform our sense of self-awareness, and the ways in which we continue to evolve our curricula to be inclusive of all students.

Finally, it is important to note that inclusion here does not mean that the classroom is simply an identity and viewpoint validation exercise, or that students coming in with previously held dogmas on various issues should leave college with those views unchallenged. Inclusion means creating an environment where exposure to diverse experiences are structured into the course, helping students strengthen themselves socially, emotionally and mentally. It also means providing students formative experiences in constructive approaches to intercultural dialogue that they may not have experienced in the past. An inclusive classroom is one of many moving parts, that is adaptable to the voices of the students in the course. In this vein, the voices of the students in response to inclusive approaches is key to reflecting on if they actually felt included. For example, after an introductory biology course implemented using this model, a departing student left this message—"Thank you for this semester's experience. Even though I am not an A student yet, being part of this community made me want to be". Explicit incorporation of inclusion need not affect course rigor or content sophistication. Sink or swim pedagogical models assume that all incoming students had access to a pool. An inclusive, facilitative approach however is understanding of the past, and designed to usher students into a space where mutual respect forms the basis for intellectual dialogue. For this space to occur, there needs to be an atmosphere of trust and community in the classroom that allows each individual to feel that everyone, including themselves is fully invested in their success. As the nation continues to struggle to retain URM students in STEM majors, a systematic overhaul of

how we think about classroom pedagogy may be necessary. Deep teaching offers a model for the transformation of not just teaching, but the liberation of education as a whole.

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