Chapter 5

What Does It Mean to Think Like a Chemist?

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The expectations of what a chemist should be, are determined by our epistemologies, that is, the accepted mechanisms through which we produce knowledge shape our conception of the "chemist". One of the "professional skills" that centered on reform curricula is critical thinking. However, in the chapter I argue that critical thinking definitions often fail to acknowledge the socio-cultural nature of science, the role of context, and how the discipline's epistemology define what is considered critical thinking. The aim of this chapter is to present the Resources for Equitable Activation of Chemical Thinking (REACT) Framework that centers equity and justice principles to foster the learning of disciplinary tools and methods in chemistry. Engagement refers to a learner's focus, participation, and persistence on a given task. The REACT framework is centered around the learner's engagement with the discipline of chemistry during a particular experience (e.g., A laboratory session, an active learning activity, a lecture session). Engagement in chemical thinking depends on both the resources the learner has as well as on the experience design and learning environment. Connecting these two aspects together moves scholars and practitioners away from deficit thinking approaches to a framework that acknowledges systemic power, resource, and participation differentials consistently hindering the scientific development of marginalized students. The REACT framework has the practical goal of providing researchers, practitioners, and evaluators with a theoretical foundation to improve learning environments in chemistry by giving them a measurable outcome: maximizing learner's engagement. Furthermore, the framework is centered around the equity mechanism of epistemological border crossing which provides a clear guideline to transform the way we teach and learn chemistry.

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"Do work that matters. Vale la pena"
– Gloria E. Anzaldúa

Introduction

Reflecting on what we commonly think of as a "chemist" as well as the skills and knowledge that they hold, can provide a foundation for rethinking critical thinking and student engagement in chemistry education. The expectations of what a chemist must be are determined by our *epistemologies*, that is, the accepted mechanisms through which we produce knowledge shape our conception of the "chemist". Chapter 1 of this book, provided the historical context and origin around the term "professional skills", and how it was driven by employer's perception of what made a chemist successful in the industry (*1*). This policy pressure from outside stakeholders from higher-education have over time finetuned our conceptions of chemists, their knowledge, and their skills; all of which require chemistry education to transform what is taught in the classroom and practiced in the laboratory. One of the "professional skills" that currently is centered on by reform curricula is *critical thinking* (*2*, *3*). However, in the chapter I argue that critical thinking definitions often fail to acknowledge the socio-cultural nature of science, the role of context, and how the discipline's Eurocentric epistemology define what is considered critical thinking.

The objective of this chapter is to present the "Resources for Equitable Activation of Chemical Thinking" *(REACT)* Framework. The REACT framework centers around the learner's engagement with the chemistry discipline during a particular experience. The REACT framework has the practical goal of providing researchers, practitioners, and evaluators with a theoretical foundation to improve learning environments in chemistry by giving them first a measurable disciplinary outcome: **maximizing** learner's *engagement in chemical thinking* (*4*, *5*). Second, the framework is centered around the equity mechanism of *epistemological border crossing* which provides equity and justice guidelines to transform the way we teach and learn chemistry (*6–8*).,

From Critical Thinking to Engagement in Chemical Thinking

Critical thinking is (*9–12*) a core concept at the heart of the goals of chemistry education, but is also, first and foremost, a normative concept. That is, critical thinking must meet certain norms and criteria in order to be considered "good". Thinking that fails to meet these criteria is therefore deemed uncritical (*13*, *14*).

Although current industry expectations deem *critical thinking* an essential "professional skill", it lacks a concrete definition that can guide curriculum design and research. Consequently, scholars in education have often referred to critical thinking as a concept that is cognitive in origin, that is, when a student is proficient at certain mental processes (*9–11*). The problem with seeing critical thinking as just a cognitive process, is that it centers only the internal process of the individual and carrying out a set of procedures mechanically, without thinking on the context or the discipline's epistemology. Instead of defining critical thinking as a set of skills, I propose we see it as the engine of our critical practices (*9*) in a discipline, such as chemistry. This includes social practices, such as 1) mentorship in a research laboratory setting, 2) the emphasis of Eurocentric ways of knowing, 3) systemic inequities that oppress groups in intersectional ways, and 4) disciplinary knowledge and practices (*15–22*). From this point on, I will refer to this concept as *chemical thinking* in lieu of *critical thinking.* This deliberate choice emphasizes the importance of context and the discipline's epistemology (Figure 1).

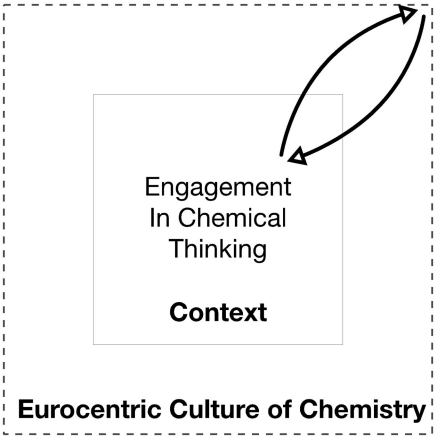

Figure 1. Current conceptions of engagement in chemical thinking as interrelated to the Eurocentric culture of chemistry.

Chemical thinking has been previously defined as "The development and application of chemical knowledge and practices with the main intent of analyzing, synthesizing, and transforming matter for practical purposes (*5*)." I want to extend this definition to center equity and justice practices in the application and teaching of chemical knowledge. The principles and criteria governing the behavior of chemists are not arbitrary or inexplicable, nor can they be divorced from contexts unique to each discipline. These behavioral principles can be identified, analyzed, and shaped by societal norms varying across different disciplines and the current colonized understanding of science, generally, and chemistry, specifically. If chemical thinking is "good thinking" in our disciplinary context, then it requires using a framework of intellectual resources that challenges current socially-approved patterns of thinking and behaviors. Students in a classroom will possess these resources to a greater or lesser extent depending on their prior access and personal epistemology. The ability to think critically does not reflect purported intelligence or academic prowess, but rather highlights familiarity with a set of socially learned patterns of behavior, where access is controlled by inequitable social systems.

The context in which engagement in chemical thinking occurs and the Eurocentric culture of chemistry, are presented as nested cultural levels in Figure 1. Describing the relationship between the two cultural levels was the first step in creating the REACT framework. I will now define these two levels within the next section of the chapter. Each subsequent section will build on the last, guiding the reader through the reasoning and decision-making process behind the framework and its complexity. Finally, I will provide an specific example on how to apply the framework in a research and practical setting.

Cultural Levels as the Basis of the REACT Framework

Chemistry Eurocentric Epistemology

It is first important to recognize, that chemistry is a discipline built on scientific colonialism. *Scientific colonialism* refers to the structure of knowledge, practices, and power that were created as a result of the transatlantic slave trade (chattel slavery), and the age of imperialism (indentured labor) (*23*, *24*). These structures, were used to 1) Justify European domination over other groups, particularly Black people, 2) Create an empirical discourse where whiteness becomes the arbiter of

who is a valid observer and practitioner of science, and 3) Comodify and exploit nature in the name of scientific progress (*25–29*). The hetero-cis normative, colonist, and white supremacist nature of science ties into chemistry epistemology, and brings its own set of instructional issues when it comes to engagement with Chemistry Thinking beyond conceptual understanding.

For example, chemistry has a pictorial language unique to it that is used to explain and teach molecular principles (*30*). This language is often referred to as a "universal" language (*31*). However, knowing the symbolic representations also means knowing how to translate them, and that translation is to the dominant imperial language of science: *Academic English* (the grammar and pronunciation of chemistry follows Academic English language conventions). The uptake of the language of chemistry has a direct impact on engagement in chemical thinking (*32*). Further, this translation is meant to connect nanoscopic, macroscopic, and symbolic phenomena (*30*, *33–35*). However, is important to recognize that linguistically diverse students, often juggle many different languages depending on the context. And, when compared to their monolingual English speakers counterparts, are forced to use Academic English in order to engage with specific aspects of the chemistry discipline (*36*). This is a way in which chemistry epistemology and chemistry culture interact with the context where students engage in chemical thinking.

The Importance of Context When Engaging in Chemical Thinking

Chemical thinking always takes place in response to a particular task or experience and within a context, such as a research experience, an active learning activity, or a laboratory class (*13*, *37*). *Engagement*, broadly, refers to a learner's focus, participation, and persistence on a given task or experience (*38–42*). Connecting context and individual resources together moves scholars and practitioners away from deficit thinking approaches that center on what "students lack" to a framework that acknowledges systemic power imbalance, resource, and participation differentials that are consistently hindering the scientific development of marginalized students (*43–46*).

The first key characteristic of engagement in chemical thinking is its multidimensional nature. Research has shown that in order for successful chemical thinking, the learner must engage in four types of processes:

- *Disciplinary engagement* focuses on whether the moment-by-moment learner behaviors and thought processes are consistent with the discipline's epistemic practices (*12*, *47–49*).
- *Affective engagement* focuses on the intensity of emotions that occur as part of completing a task and whether they are positive or negative (*50*, *51*). Willingness or positive affective processes towards argumentation practices have shown to be important factors in supporting student learning (*52*).
- *Social engagement* takes the form of social behavior in a learning context with peers and other scientists (*41*, *42*). Chemistry is a social process, and relies as much on the cognitive processes of the individual as with the exchange of ideas among peers (*53–56*).
- *Perceived success* is the learner's sense of how well they performed on a given task, often based on implicit or explicit feedback they receive from the instructor or peers (e.g., students in the same classroom) (*40*).

The second key characteristic of engagement is its high malleability. That is, it is very sensitive to the learning environment, and interactions with others (*51*, *57–60*). Students may experience

multiple levels of engagement throughout an educational experience, but research shows that learner resources are the ones that set the initial benchmark (*61*).

For example, studies have showed that linguistically diverse speakers have difficult asking questions (disciplinary engagement) and experience insecurity (negative affective engagement) when investigating and writing about phenomena (*35*). If curriculum design or instructors assume the chemistry language uptake is homogenous, non-native speakers will be placed in a situation with direct barriers towards their engagement. It is important to clarify that there is plenty of evidence of the cognitive benefits for children that speak more than one language (*62–64*). Multilingualism should be seen as an asset and not the source of learning deficits and problems; the benefits of multilingualism do not erase the need for support for learners who are not fluent in the dominant language.

Those students that have a different epistemology for understanding nature or that embrace other funds of knowledge (like language) are forced to either make future decisions that avoid science or reject crucial parts of their identities. However, researchers and educators can make changes that allow students to succeed in equitable ways by supporting their *epistemological border crossing* (*6*, *8*, *65*).

Epistemological Border Crossing

Epistemological Border Crossing is a term extrapolated from Gloria Anzaldúa's work Borderland/LaFrontera (*6*). Borderland Crossing refers to the way actors negotiate contradictions and tensions by belonging to two different cultures at once, in the case of the REACT framework, ways of knowing nature (*66*, *67*). Those who live among multiple worlds inhabit *nepantla* (the in-between space), and seek to resist the forced dichotomy of colonialism where you need to choose one over the other (*8*, *16*, *68*, *69*).

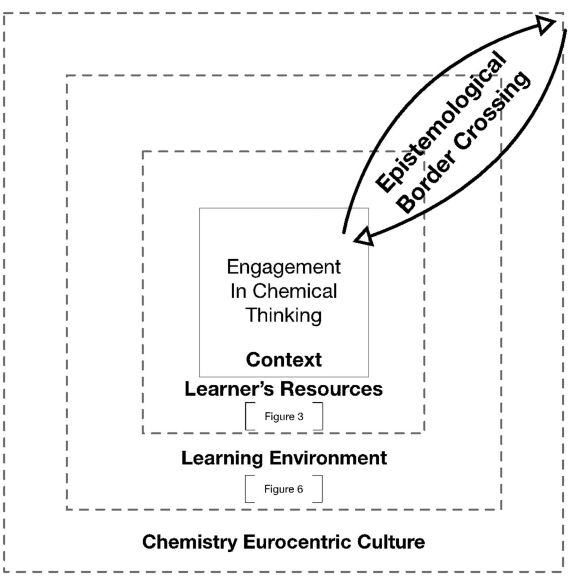

Figure 2. Dynamic, multi-level structure of culture as foundation for the REACT framework.

In order to conduct Chemistry Education Research (CER) that supports marginalized student's border crossing, there is a need for a theoretical framework that: 1) Identifies the factors that influence engagement in chemical thinking, 2) Acknowledges the process that can inhibit

epistemological border crossing, and 3) Classifies different stressors of inequity on their respective cultural level, so researchers will be able to target the correct stakeholders to enact change. Therefore, the REACT framework follows a dynamic, multi-level structure of culture, that allows for the examination of the nested structure from macro to micro levels and how they interact with each other (Figure 2). The dynamic model also acknowledges that grassroots efforts can have important impact from a bottom-up approach (*70–72*). It is possible that a particular research study or intervention that uses the REACT framework does not attend to every cultural level or factor. The important thing is that both researchers and practitioners are cognizant of the limitations of their approach and how the omission of certain factors or acknowledgements can hinder equity changes. The remaining sections of the chapter, will highlight each cultural level from a bottom-up approach. Furthermore, Figure 2 also provides a guide to how the subsequent figures on the manuscript fit in to build the final version of the framework. As the most important stakeholder when it comes to maximizing engagement is the learner, the next section will deep dive into learner's resources.

Learner's Resources

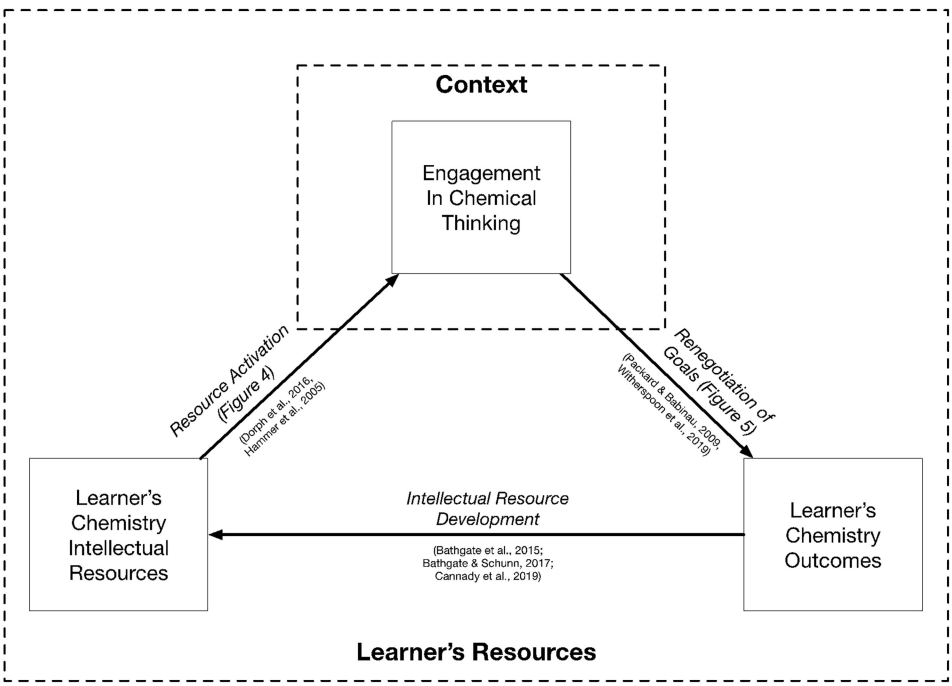

Figure 3. Chemistry Learner Activation Triangle. In the diagram arrows represent the processes or connection between variables, while boxes represent the variables that participate on the process. As one can see there are three processes in action: 1) resource activation (Figure 4), 2) renegotiation of goals (Figure 5), and 3) intellectual resource development.

In order to engage with a new chemistry experience, or lesson, a learner will make use of their intellectual resources, as well as leverage their past experiences and personal epistemology. It is important to note that, focusing on identities like race, gender, and socio-economic status can provide us with descriptive information of which marginalized populations are not served correctly. However, ascribing these descriptive differences to the identities themselves creates arguments rooted on biological determinism. It is important to remember imposed and chosen identities like

race and gender, among others, are social constructs. Therefore, as researchers and instructors we must be careful on the interpretation and weight we give to categories as social constructs, and understand social constructs are not meant to be part of causal explanations (*73*).

When it comes to what a learner brings into an experience, it is better that we focus on *semi-malleable factors*, that is, constructs that can be shaped and changed through multiple experiences. Semi-malleable factors are stable enough through time to be good factors of engagement, but malleable enough that we can intervene on them. In this case, the REACT framework focuses on a class of semi-malleable factors called *intellectual resources* and their interaction with prior experiences. Figure 3, shows the connection between the three concepts, referred to as the *Chemistry Learner Activation Triangle* (*61*).

Resource Activation

Intellectual resources refer to three malleable and interrelated categories: knowledge, skills, and dispositions that learners bring into the classroom.

Knowledge

- *Chemistry Content Knowledge* A chemist must to have a working knowledge of the fundamental facts of the science (*3*, *74*, *75*). That is, not just memorized facts, but also understanding symbolic representation and the dynamic nature of molecules, among other central tenants of chemistry, for example (*76*, *77*).
- *Personal Epistemology* is broadly defined as how students understand the nature of knowledge, the process of learning (*78–80*). Personal epistemology, is the product of student's cultural ways of knowing (approach to understanding the natural world), and funds of knowledge (Household's bodies of knowledge and skills that have been developed through the accumulation of a family's history and culture) (*81*, *82*).

Chemistry Sensemaking refers to the general mastery level of chemistry practices and how they are used in the process of building an explanation to resolve a perceived gap or conflict in knowledge (*19*, *83*).

Chemistry Dispositions

- *Chemistry Self-Efficacy* refers to the beliefs about having chemistry-related skills and being able to successfully complete chemistry-related tasks (*84–87*).
- *Chemistry Fascination* is the interest in and mastery goals for chemistry content and skills (*59*, *84*, *85*).
- *Chemistry Identity* refers to the self-perception and other perceptions of student as a science type of person (*88–90*).

Historically, people have used the term *resource transfer* to refer to learner's ability to apply intellectual resources across different contexts (*91*).

However, under this perspective, the success of failure of *resource transfer* is centered on the learner (*91*, *92*). Instead, Hammer suggests the use of the term *resource activation,* which refers to how the learning context gives cues and supports the student's intellectual resources (*92*). The REACT

Framework expands this definition of activation to include how an individual's epistemology relates to resource activation, and how experience design and implementation are moderators of it. Therefore, the use of *resource activation* rather than *resource transfer* is purposeful within the framework. Resource transfer refers to whether knowledge or skills an individual acquires can be brought to another situation. The impact of experience design and implementation will be addressed in the next section.

Given that engagement represents expected behaviors, it is important that each engagement type, is directly mapped to the intellectual resources' students may bring into the classroom. Without this mapping it would be difficult to design targeted experiences meant to leverage intellectual resources to produce high engagement. In general, higher levels of intellectual resources are associated with higher engagement. Figure 4 represents the current understanding of how intellectual resources relate to engagement in chemical thinking.

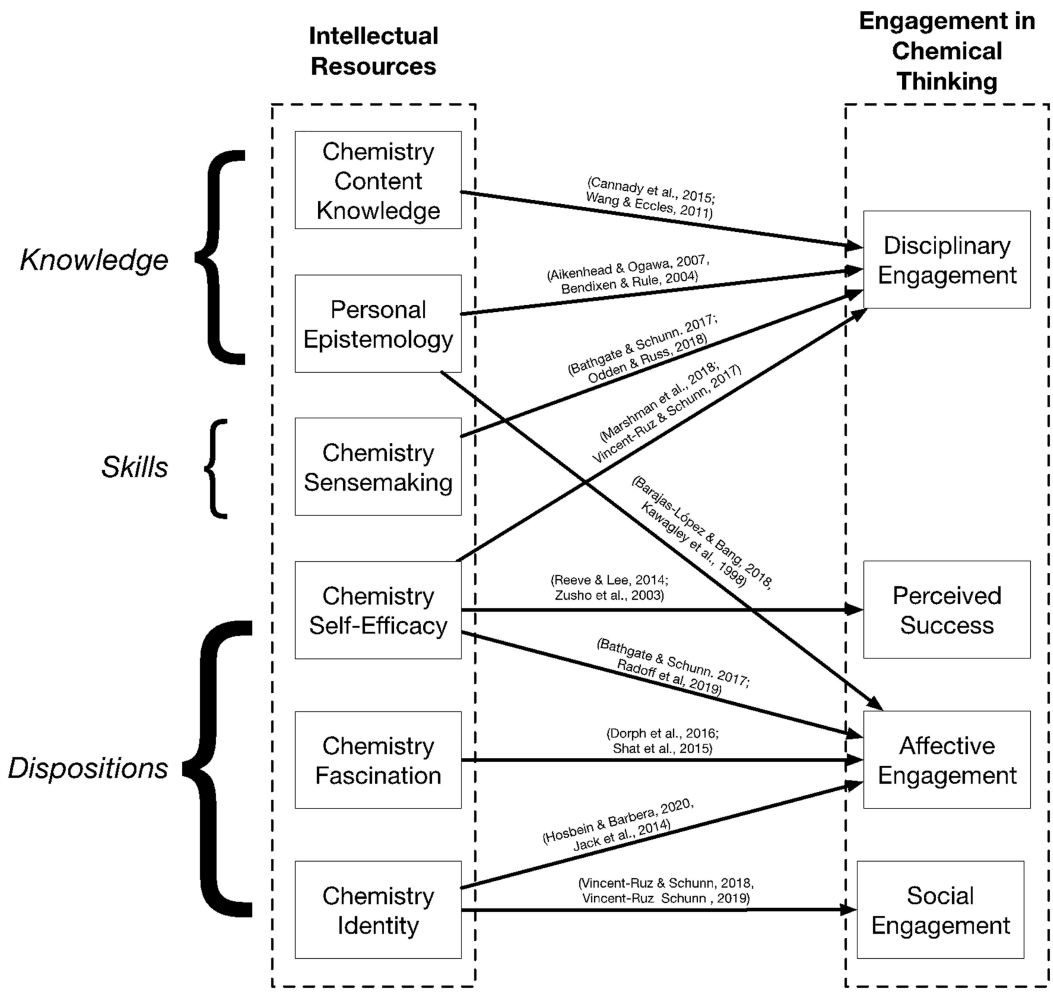

Figure 4. Relationship between intellectual resources and engagement in chemical thinking.

Renegotiation of Goals

When border crossing is successful (or students are not force to engaged in the process due to privilege), engagement in chemical thinking translates to proximal learner outcomes (Figure 5). However, when it is not successful students may renegotiate their expectations and goals, by choosing pathways away from chemistry or STEM overall (*93*).

The outcomes highlighted are meant to look at success in STEM and chemistry beyond just grades and retention.

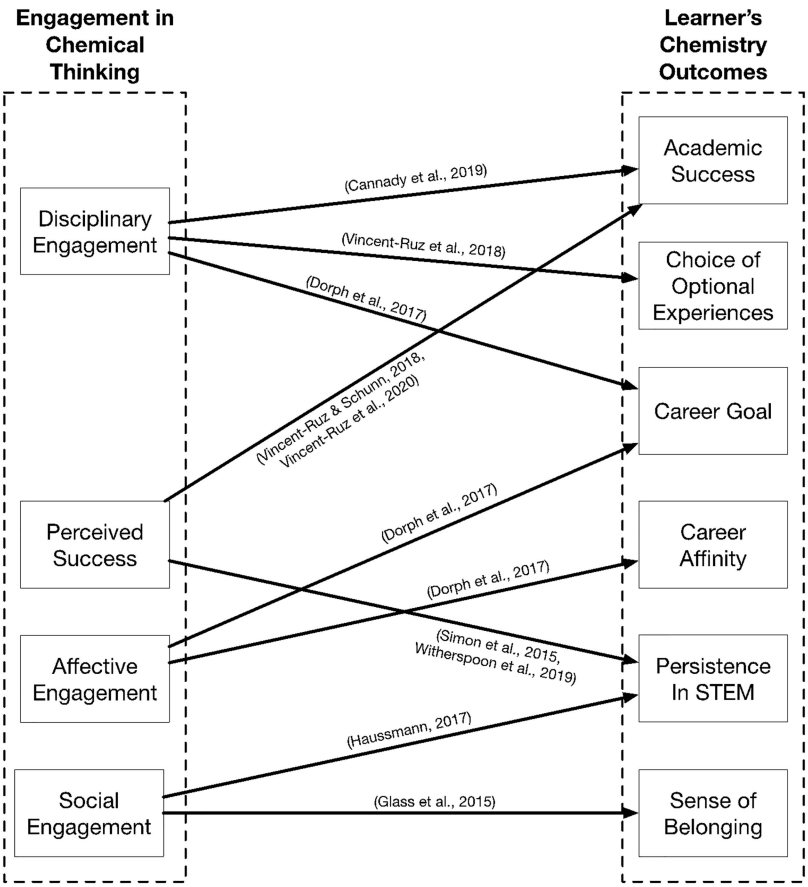

Figure 5. Relationship between dimensions of engagement in critical thinking and learner's chemistry outcomes.

- *Academic Success* – Refers to the traditional ways of defining success in STEM education literature. This can be studied through grades, homework or exams. However, it is crucial to not equate academic success to domain knowledge (*94*).
- *Choice of Optional Experiences* – Students may choose certain subjects in college because they are requirements for their major. Pre-med students may not have an interest for chemistry as a subject but it is necessary for med school admissions (*93*). Therefore, another marker of success is when students make choices beyond introductory courses. This can be in the form of taking advanced coursework related to chemistry as a major or undergraduate research experiences (*95*).
- *Career Goal* – Refers to the specific career or major a learner wants to have (*96*).

- *Career Affinity* – Relates to the degree in which a learner wants a specific subject or discipline to be related to their major or career (*96*). A learner may not want to major in chemistry but may be interested in a career in biology that focuses on molecular interactions, for example.
- *Persistence in STEM* – Persistence in STEM is referred as whether the choices a student makes in their career keeps them connected to a STEM subject. This can be observed by the subjects they choose or stop taking in college, or the way they apply their career.
- *Sense of Belonging* – Sense of belonging refers to whether students feel belonging among their peers or faculty (*97*). Marginalized students often cite this factor as one of the many difficulties in their STEM careers (*97–104*).

Intellectual Resource Development

Intellectual resources are developmental in nature, and molded in diverse contexts that span many years and involve many formats. That is, they are shaped through multiple experiences over time (*92*, *105*). Therefore, they reflect access inequities (*35*, *36*, *62*, *106*).

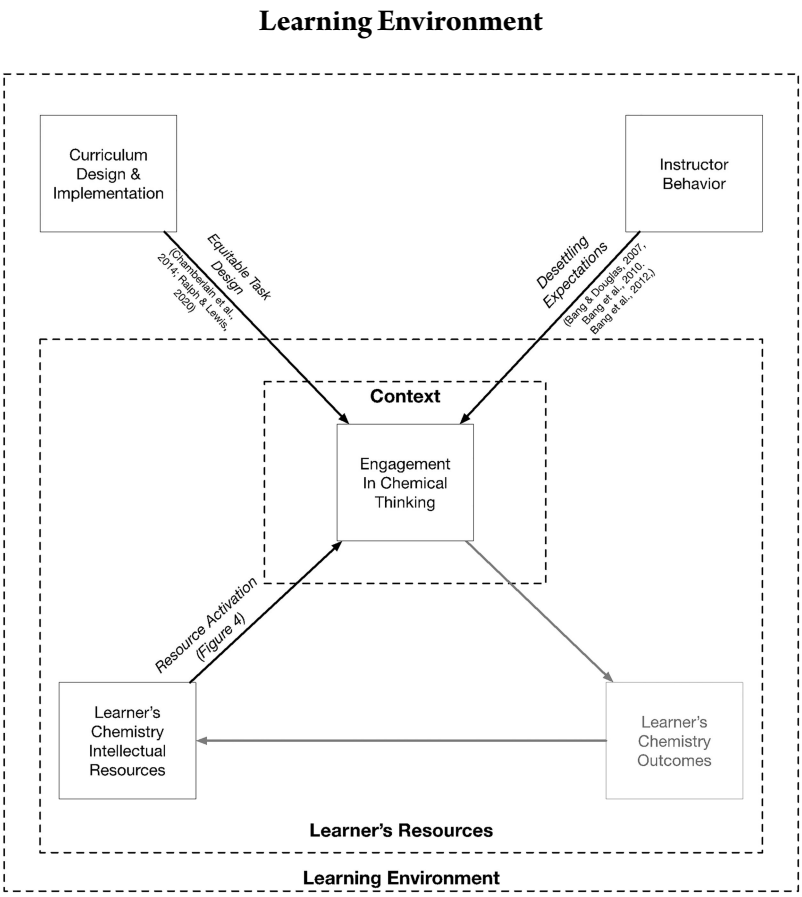

Figure 6. Key factors of the learning environment that supports resource activation for engagement in chemical thinking.

The learning environment refers to the methods of teaching, assessment, and activities that impact the learner's engagement. The main stakeholder at this level is the college instructor. It follows that different teaching methods or instructor behavior would produce different engagement behaviors. Furthermore, there is a need to increase our understanding of chemistry STEM knowledge-centered environments that emphasize the need to help students learn the well-organized bodies of knowledge that support understanding and adaptive expertise that scientists need in their professional careers (*107*). In this section I will talk about our current understanding on how curriculum design and instructor behavior impact Engagement in Chemical Thinking, specifically on the *resource activation* process highlighted in the previous section (Figure 6).

Instructor Behaviors

In general, student outcomes increase when instructors are provided with instructional strategies when implementing science curriculum (*108*). Despite being an under-studied area, teacher beliefs and conceptions are the most important factor on how interventions are implemented, and whether they are successful (*109*, *110*). Teacher beliefs are also a reason why interventions may be able to increase student's performance overall but not change outcomes in an equitable way. Often the conversion has focused on instructors implicit biases as a primary source of inequality (*111–113*). While mitigating our own biases is key to becoming good instructors, it must be situated within a larger conversation to confront history, impacts of structural racism and take action to interrupt inequitable systems.

For example, instructors in college often rely on individualistic fixed beliefs on inequality. Generally speaking, individualistic beliefs about inequality means that if someone does not earn a college degree or earn a middle-class income, then that person is to blame for not achieving or earning more in life. When justifying meritocracy as a source of differences across groups, instructors often rely on connecting race, socioeconomic, and gender beliefs to reinforce negative views of groups in a biological deterministic way, which supports white supremacist views (*114–116*).

Furthermore, the constant reinforcement of stereotypes about members of different groups, can solidify in people's minds that inequality may be rigid or fixed, meaning that little can be done to make society more equitable after a certain point. Thus, people may exhibit a "fixed inequality mindset" and situate social inequalities as the result of past experiences or obstacles that cannot be overcome in the present or future. This often leads instructors to resist changing their behavior to support marginalized students.

Furthermore, typically instructors don't support students when conflicts and contradictions arise in terms of student's meaning making through their personal epistemology and Eurocentric ways of knowing (*117*). This is to no surprise, instructors in college rarely get any training in teaching, when we add to that a fixed inequality mindset we set up marginalized students for failure in terms of epistemological border crossing (*118*, *119*).

There is little research in chemistry education, and in education overall, about how educators can be more sensitive to student contexts and experiences that do not rely on viewing their outcomes as mostly a result of their individual efforts and capacities (*118*, *120*, *121*). Leaving "What strategies exist to assist with shifting college instructors' beliefs about and actions toward students that do not reinforce such a mindset?" as an important research target to support equity efforts.

Curriculum Design and Implementation

There is very little research that looks at the interplay of curriculum materials and teacher beliefs and practices (*122*). The majority of the Chemistry Education Research has focused on how to maximize disciplinary engagement, particularly in chemistry practices, students' mathematical reasoning, conceptual integration, and writing to learn, and mechanistic reasoning (*14*, *123–128*). There is less evidence when it comes to the effectiveness or impact of laboratory courses on chemical thinking or how any of these instruction types impact affective or social engagement (*129*).

From this corpus of work there are specific practical implications in terms of equitable task and curriculum design. First, scaffolding is associated with positive affective engagement and increased perceived success (*130*, *131*). Second, peer review can be an effective social engagement tool that has an impact in conceptual understanding and scientific writing skills (*132*, *133*). Third, situations of supported autonomy also positively impact perceived success (*134*). Finally, the way models are presented to students, and the design of multi-modal assessments, can elicit students disciplinary engagement and allow them to better understand and present their ideas (*36*, *135*).

However, it is also important that curriculum design goes through a desettling process (*117*). To design within a desettling frame as defined by Bang et al., means to: "understand and take up these knowledge-power relations – and assumed assimilation into particular knowledge paradigms – as an explicit object of inquiry in the science classroom (*117*)." Curriculum should be designed to subvert dominant epistemologies in science, so that teachers and local communities can reframe the knowledge in a way that centers the needs of communities and applications of science in an equitable and just way (*136*). For example, one could do a study uncovering marginalized students thinking and decision-making, and study how they apply their funds of knowledge and personal epistemology to engage with science knowledge without judgement (*4*). This student-centered approach can then be applied to curriculum design by applying this new knowledge to other more general approaches to equitable task design. It is imperative that instructors also support the dismantling of policies and structures that hold inequity in place. Not everything can be done within the classroom, but instructor commitment to change can affect the way the institution makes policy decisions (*137*).

Implications for Research and Practice

This chapter introduced the Resources for Equitable Activation of Chemical Thinking *(REACT)* Framework (Figure 7). The nested structure of the classroom is purposeful so practitioners and researchers can better understand the variety of factors that impact student learning in chemistry. It is important to note that the purpose of the REACT Framework is not to promote the idea that only studies that look at macro and micro interactions are valid in Chemistry Education Research. Its goal is to provide researchers theoretical guidance on the possible understudied factors in our field, as well as the limitations of our conclusions when focusing only on internal learner characteristics. To finalize this chapter, I will presen an example of how to apply the REACT framework, either as a practitioner or researcher.

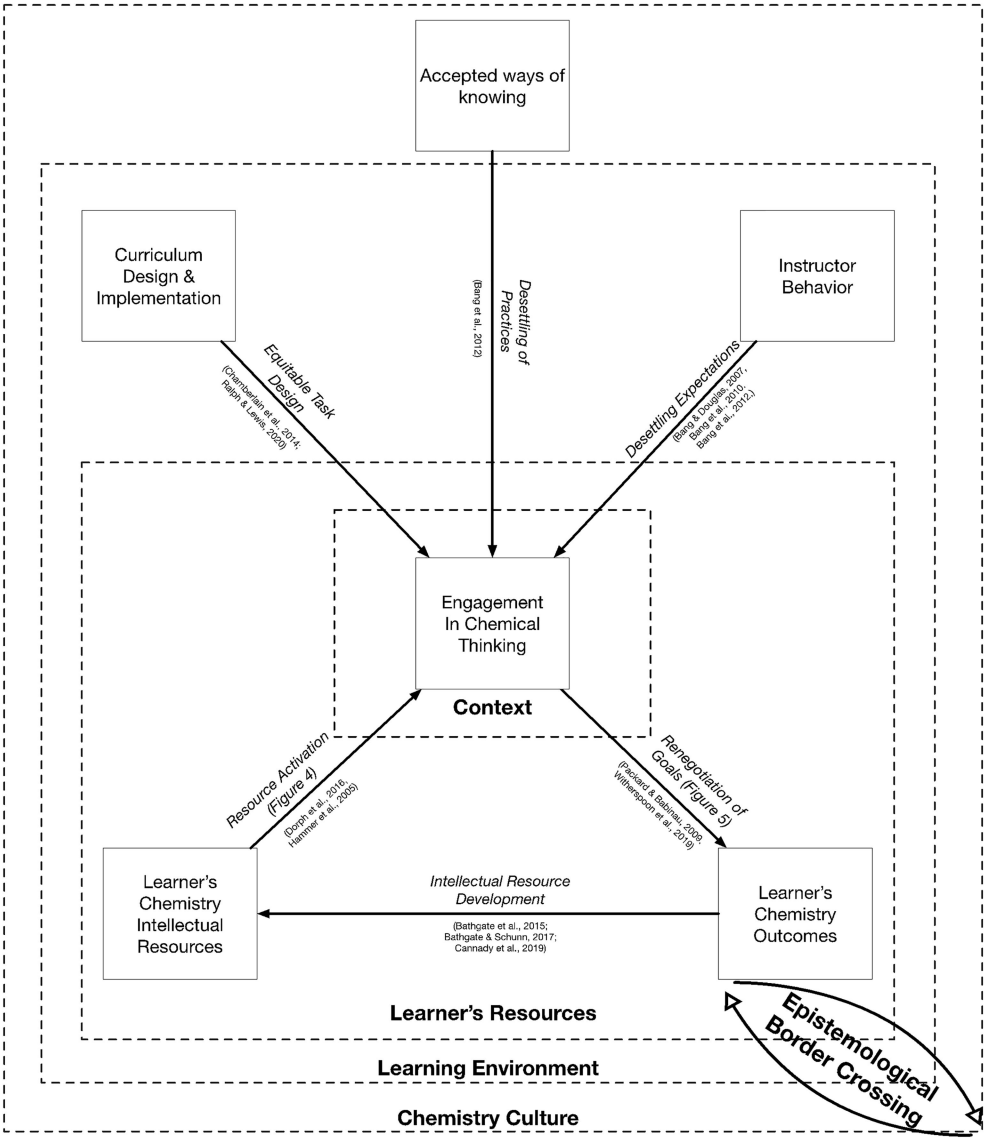

Figure 7. Resources for Equitable Activation of Chemical Thinking (REACT) framework.

Strategies to Support Students with Physical Disabilities in a Laboratory Instructional Setting

Science laboratory classes pose unique problems for students with disabilities. Generally, adaptations for students happen on a student to student basis or informal settings (*138*). However, this means that students often need to ask for support rather than walk into an environment that already saw them as legitimate participants (*139*). Nelly, worked with students with disabilities to create a curriculum of laboratory classes that would have adaptive strategies for students with disabilities as the central design tenet (*140*). The curriculum explicitly acknowledged the inequitable structure and made the modifications part of the culture of the laboratory classes (it is possible that further accommodations may be necessary as the needs of students with disabilities are not monolithic). Applying the REACT framework to this work shows how instructors could hypothetically study whether the accommodations support students sense of belonging (Figure 8).

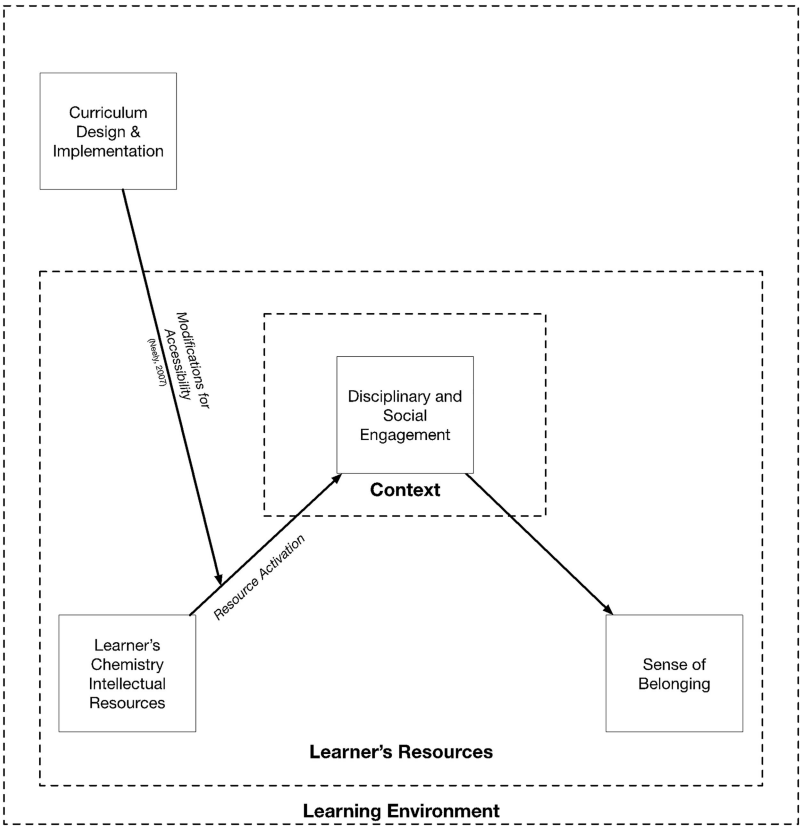

Figure 8. REACT framework applied to support students with disabilities in the laboratory classroom.

The traditional laboratory setting is a barrier that hinders the disciplinary and social engagement of students with disabilities. According to the react framework, student's lack of engagement is not because they don't have the necessary intellectual resources, but because the traditional learning environment hinders their activation. The modifications activate the intellectual resources and support the epistemological border crossing of students with disabilities allowing them to participate both in social and disciplinary practices. An instructor could interview, for example, students at the beginning of the class to understand how past accessibility issues have affected their chemistry identity. At the end of the semester instructors could re-interview students to understand how the implementations supported their sense of belonging. If this example were to be applied to a research project the same theoretical principles apply. However, methodologically, researchers may want to use videos to run a qualitative study of how student engagement looks like both in a modified and traditional setting. This approach may create a better description of what epistemological border crossing entails on this particular setting.

Closing Remarks

Engagement in Chemical Thinking provides researchers and practitioners with a malleable outcome to target the development of critical chemistry related skills and achieve equitable outcomes. By expanding the notion of critical thinking to include not only cognitive engagement, we are allowing a more holistic view of the student.

The field currently needs a deeper understanding of how characteristics of learning environments can help activate learner's engagement despite their past experiences or intellectual resources. This research could have an important impact on equitable outcomes, as well as provide instructors with a set of tools to leverage according to the needs of their students. With few exceptions, most instructional level transformations in chemistry happen decoupled from a department's overall educational mission. This makes it difficult for instructors and chemistry education researchers to create long lasting transformations. Furthermore, research focused on curriculum development that is not coupled with an understanding of teacher's beliefs and resistance may fail to produce positive student outcomes.

Future work should also focus on the role of institutional identity and its impact on instructor choices and resources (72). Higher Education research has shown this cultural level has important impact on equity outcomes. However, the understanding on how that affects chemistry is not understood.

Finally, equity work is not a methodology or the inclusion of diverse groups in a sample. A true commitment to equity research is centering those principles in every decision we make as researchers and practitioners. If chemists want to participate in equity efforts efforts, then they need to listen, educate themselves, and live by the principles even when it is uncomfortable or hard. By introducing the mechanism of epistemological border crossing, the REACT Framework is not only providing a starting point to do equity centered research, but a theoretical framework centered on the needs of the marginalized students.

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References

1. Whitmore, F. C. What An Employer Expects Of A Chemist. *Symposium On What Industry Wants Of Its Chemists* **1937**, 267–268.
2. Headrick, K. L. Want Ads, Job Skills, And Curriculum: A Survey Of 1998 Chemistry Help-Wanted Ads. *J. Chem. Ed.* **2001**, *78*, 1281.
3. Yasin, N. Y. B. M.; Yueying, O. Evaluating The Relevance Of The Chemistry Curriculum To The Workplace: Keeping Tertiary Education Relevant. *J. Chem. Ed.* **2017**, *94*, 1443–1449.
4. Banks, G.; Clinchot, M.; Cullipher, S.; Huie, R.; Lambertz, J.; Lewis, R.; Ngai, C.; Sevian, H.; Szteinberg, G.; Talanquer, V.; Weinrich, M. Uncovering Chemical Thinking In Students' Decision Making: A Fuel-Choice Scenario. *J. Chem. Ed.* **2015**, *92*, 1610–1618.
5. Sevian, H.; Talanquer, V. Rethinking Chemistry: A Learning Progression On Chemical Thinking. *CERP* **2014**, *15*, 10–23.
6. Anzaldua, G. *Borderlands The New Mestiza = La Frontera*; Aunt Lute Books: San Francisco, Calif, 1987;
7. Naples, N. A. Borderlands Studies And Border Theory: Linking Activism And Scholarship For Social Justice. *Sociol. Compass* **2010**, *4*, 505–518.

8. Veintie, T. Practical Learning And Epistemological Border Crossings: Drawing On Indigenous Knowledge In Terms Of Educational Practices. *Diaspora, Indigenous, And Minority Education* **2013**, *7*, 243–258.
9. Abrami, P. C.; Bernard, R. M.; Borokhovski, E.; Waddington, D. I.; Wade, C. A.; Persson, T. Strategies For Teaching Students To Think Critically: A Meta-Analysis. *Review Of Educ. Res.* **2015**, *85*, 275–314.
10. Pithers, R. T.; Soden, R. Critical Thinking In Education: A Review. *Educ. Res.* **2000**, *42*, 237–249.
11. Puig, B.; Blanco-Anaya, P.; Bargiela, I. M.; Crujeiras-Pérez, B. A Systematic Review On Critical Thinking Intervention High. Educ. Stud Across Professional Fields. *High. Educ. Stud* **2019**, *44*, 860–869.
12. Stowe, R. L.; Cooper, M. M. Practicing What We Preach: Assessing "Critical Thinking" In Organic Chemistry. *J. Chem. Ed.* **2017**, *94*, 1852–1859.
13. Bailin, S. Critical Thinking And Science Education. *Sci. Educ.* **2002**, *11*, 361–375.
14. Bain, K.; Rodriguez, J.-M. G.; Towns, M. H. Chemistry And Mathematics: Research And Frameworks To Explore Student Reasoning. *J. Chem. Educ.* **2019**, *96*, 2086–2096.
15. Aikenhead, G. S.; Ogawa, M. Indigenous Knowledge And Science Revisited. *Cult. Stud. Sci. Educ. Education* **2007**, *2*, 539–620.
16. Bang, M.; Medin, D. L.; Atran, S. Cultural Mosaics And Mental Models Of Nature. *PNAS* **2007**, *104*, 13868.
17. Bhushan, N.; Rosenfeld, S. Metaphorical Models In Chemistry. *J. Chem. Ed.* **1995**, *72*, 578.
18. Bucat, R. Pedigagocial Content Knowledge As A Way Forward: Applied Research In Chemical Education. *CERP* **2004**, *5*, 215–228.
19. Cannady, M. A.; Vincent-Ruz, P.; Chung, J. M.; Schunn, C. D. Scientific Sensemaking Supports Science Content Learning Across Disciplines And Instructional Contexts. *Contemp. Educ. Psychol.* **2019**, *59*, 101802.
20. Crenshaw, K. W. *On Intersectionality: Essential Writings*; The New Press: 2017;
21. Klymkowsky, M. W. Thinking About The Conceptual Foundations Of The Biological Sciences. *CBE Life Sci. Educ.* **2010**, *9*, 405–407.
22. Wei, C. A.; Woodin, T. Undergraduate Research Experiences In Biology: Alternatives To The Apprenticeship Model. *CBE Life Sci. Educ.* **2011**, *10*, 123–131.
23. Clarke, S.; Walsh, A. Scientific Imperialism And The Proper Relations Between The Sciences. *Int. Stud. Philos.* **2009**, *23*, 195–207.
24. Hira, S. Scientific Colonialism: The Eurocentric Approach To Colonialism Eurocentrism, Racism And Knowledge: Debates On History And Power In Europe And The Americas. *Eurocentrism, Racism and Knowledge.* **2015**, 136–153.
25. Fuentes-George, K. Neoliberalism, Environmental Justice, And The Convention On Biological Diversity: How Problematizing The Commodification Of Nature Affects Regime Effectiveness. *Global Environmental Politics* **2013**, *13*, 144–163.
26. Laituri, M. Indigenous Peoples' Issues And Indigenous Uses Of Gis. *The SAGE Handbook Of GIS And Society* **2011**, *1996*, 202–221.

27. Prescod-Weinstein, C. Making Black Women Scientists Under White Empiricism: The Racialization Of Epistemology In Physics. *Signs: Journal Of Women In Culture And Society* **2020**, *45*, 421–447.
28. Zuberi, T. *Thicker Than Blood: How Racial Statistics Lie*; U Of Minnesota Press: 2001;
29. Zuberi, T.; Bonilla-Silva, E. *White Logic, White Methods: Racism And Methodology*; Rowman & Littlefield Publishers: 2008
30. Crosland, M. P. *Historical Studies In The Language Of Chemistry*; Courier Corporation: 2004
31. Kornberg, A. The Universal Language. *Bio/Technology* **1987**, *5*, 520.
32. Markic, S.; Childs, P. E. Language And The Teaching And Learning Of Chemistry. *CERP Chem. Educ. Res. Pract.* **2016**, *17*, 434–438.
33. Ford, A.; Peat, F. D. The Role Of Language In Science. *Foundations Of Physics* **1988**, *18*, 1233–1242.
34. Laszlo, P. Towards Teaching Chemistry As A Language. *Sci. Educ.* **2013**, *22*, 1669–1706.
35. Lee, O. Science Education With English Language Learners: Synthesis And Research Agenda. *Review Of Educ. Res.* **2005**, *75*, 491–530.
36. Ryoo, K.; Toutkoushian, E.; Bedell, K. Exploring Different Types Of Assessment Items To Measure Linguistically Diverse Students' Understanding Of Energy And Matter In Chemistry. *CERP* **2018**, *19*, 149–166.
37. Bailin, S.; Case, R.; Coombs, J. R.; Daniels, L. B. Conceptualizing Critical Thinking. *J. Curric. Stud.* **1999**, *31*, 285–302.
38. Appleton, J. J.; Christenson, S. L.; Furlong, M. J. Student Engagement With School: Critical Conceptual And Methodological Issues Of The Construct. *Psychology In The Schools* **2008**, *45*, 369–386.
39. Bathgate, M. *Examining Motivational Shifts In Middle School: What Deepens Science Motivation And What Attenuates Its Decline*. 2016, University of Pittsburgh
40. Bathgate, M.; Schunn, C. The Psychological Characteristics Of Experiences That Influence Science Motivation And Content Knowledge. *Int. J. Sci. Educ.* **2017**, *39*, 2402–2432.
41. Fredricks, J. A.; Blumenfeld, P. C.; Paris, A. H. School Engagement: Potential Of The Concept, State Of The Evidence. *Review Of Educ. Res.* **2004**, *74*, 59–109.
42. Fredricks, J. A.; Wang, M. T.; Linn, J. S.; Hofkens, T. L.; Sung, H.; Parr, A.; Allerton, J. Using Qualitative Methods To Develop A Survey Measure Of Math And Science Engagement. *Learning And Instruction* **2016**, *43*, 5–15.
43. Valencia, R. R. Conceptualizing The Notion Of Deficit Thinking. *The Evolution Of Deficit Thinking: Educational Thought And Practice* **1997**, *19*, 1–12.
44. Valencia, R. R. " Mexican Americans Don't Value Education!" On The Basis Of The Myth, Mythmaking, And Debunking. *Journal Of Latinos And Education* **2002**, *1*, 81–103.
45. Weiner, L. Challenging Deficit Thinking. *Educational Leadership* **2006**, *64*, 42.
46. Zeidler, D. L. Stem Education: A Deficit Framework For The Twenty First Century? A Sociocultural Socioscientific Response. *Cult. Stud. Sci. Educ. Education* **2016**, *11*, 11–26.
47. Carmel, J. H.; Herrington, D. G.; Posey, L. A.; Ward, J. S.; Pollock, A. M.; Cooper, M. M. Helping Students To "Do Science": Characterizing Scientific Practices In General Chemistry Laboratory Curricula. *J. Chem. Ed.* **2019**, *96*, 423–434.

48. Engle, R. A.; Conant, F. R. Guiding Principles For Fostering Productive Disciplinary Engagement: Explaining An Emergent Argument In A Community Of Learners Classroom. *Cognition And Instruction* **2002**, *20*, 399–483.
49. Watts, F. M.; Schmidt-McCormack, J. A.; Wilhelm, C. A.; Karlin, A.; Sattar, A.; Thompson, B. C.; Geree, A. R.; Shultz, G. V. What Students Write About When Students Write About Mechanisms: Analysis Of Features Present In Students' Written Descriptions Of An Organic Reaction Mechanism. *CERP* **2020**.
50. Choi, A.; Melo, C. D.; Woo, W.; Gratch, J. Affective Engagement To Emotional Facial Expressions Of Embodied Social Agents In A Decision-Making Game. *Computer Animation And Virtual Worlds* **2012**, *23*, 331–342.
51. Ross, J.; Guerra, E.; Gonzalez-Ramos, S. Linking A Hierarchy Of Attitude Effect To Student Engagement And Chemistry Achievement. *CERP* **2020**, *21*, 357–370.
52. Bathgate, M.; Crowell, A.; Schunn, C.; Cannady, M.; Dorph, R. The Learning Benefits Of Being Willing And Able To Engage In Scientific Argumentation. *Int. J. Sci. Educ.* **2015**, *37*, 1590–1612.
53. Cooper, M. M.; Cox, C. T.; Nammouz, M.; Case, E.; Stevens, R. An Assessment Of The Effect Of Collaborative Groups On Students' Problem-Solving Strategies And Abilities. *J. Chem. Educ.* **2008**, *85*, 866.
54. Pickering, A. The Mangle Of Practice: Agency And Emergence In The Sociology Of Science. *Am. J. Sociol* **1993**, *99*, 559–589.
55. Pinch, T. J.; Bijker, W. E. The Social Construction Of Facts And Artefacts: Or How The Sociology Of Science And The Sociology Of Technology Might Benefit Each Other. *Social Studies Of Science* **1984**, *14*, 399–441.
56. Ryu, S.; Lombardi, D. Coding Classroom Interactions For Collective And Individual Engagement. *Educ. Psychol.* **2015**, *50*, 70–83.
57. Chamberlain, J. M.; Lancaster, K.; Parson, R.; Perkins, K. K. How Guidance Affects Student Engagement With An Interactive Simulation. *CERP* **2014**, *15*, 628–638.
58. Furrer, C. J.; Skinner, E. A.; Pitzer, J. R. The Influence Of Teacher And Peer Relationships On Students' Classroom Engagement And Everyday Motivational Resilience. *National Society For The Study Of Education* **2014**, *113*, 101–123.
59. Liu, Y.; Ferrell, B.; Barbera, J.; Lewis, J. E. Development And Evaluation Of A Chemistry-Specific Version Of The Academic Motivation Scale (Ams-Chemistry). *CERP* **2017**, *18*, 191–213.
60. Shernoff, D. J.; Kelly, S.; Tonks, S. M.; Anderson, B.; Cavanagh, R. F.; Sinha, S.; Abdi, B. Student Engagement As A Function Of Environmental Complexity In High School Classrooms. *Learning And Instruction* **2016**, *43*, 52–60.
61. Dorph, R.; Cannady, M. A.; Schunn, C. How Science Learning Activation Enables Success For Youth In Science Learning. *Electronic Journal Of Science Education* **2016**, *20*, 49–85.
62. Goriot, C.; Denessen, E.; Bakker, J.; Droop, M. Benefits Of Being Bilingual? The Relationship Between Pupils' Perceptions Of Teachers' Appreciation Of Their Home Language And Executive Functioning. *International Journal Of Bilingualism* **2016**, *20*, 700–713.
63. Marian, V.; Shook, A. The Cognitive Benefits Of Being Bilingual. *Cerebrum: The Dana Forum On Brain Science* **2012**, *2012*.

64. Nicolay, A.-C.; Poncelet, M. Cognitive Benefits In Children Enrolled In An Early Bilingual Immersion School: A Follow Up Study. *Bilingualism: Language And Cognition* **2015**, *18*, 789–795.
65. Orozco-Mendoza, E. F. *Borderlands Theory: Producing Border Epistemologies With Gloria Anzaldúa*. 2008, Virginia Tech (Doctoral Dissertation)
66. Crocker, K. C. *Unstructured Informal Interview*. *Personal Communication* 2020.
67. Vila, P. *Ethnography At The Border*; U Of Minnesota Press: 2003.
68. Bang, M.; Medin, D. Cultural Processes In Science Education: Supporting The Navigation Of Multiple Epistemologies. *Science Education* **2010**, *94*, 1008–1026.
69. Lugones, M. *From Within Germinative Stasis: Creating Active Subjectivity, Resistant Agency Entremundos/Amongworlds: New Perspectives On Gloria E. Anzaldúa*. 2005, 85-99.
70. Doran, E.; Medina, Ø. The Intentional And The Grassroots Hispanic-Serving Institutions: A Critical History Of Two Universities. *Association Of Mexican American Educators Journal* **2017**, *11*, 29–49.
71. Erez, M.; Gati, E. A Dynamic, Multi-Level Model Of Culture: From The Micro Level Of The Individual To The Macro Level Of A Global Culture. *Applied Psychology* **2004**, *53*, 583–598.
72. Garcia, G. A.; Núñez, A.-M.; Sansone, V. A. Toward A Multidimensional Conceptual Framework For Understanding "Servingness" In Hispanic-Serving Institutions: A Synthesis Of The Research. *Review Of Educ. Res.* **2019**, *89*, 745–784.
73. Holland, P. W. Causation And Race. *White Logic, White Methods: Racism And Methodology* **2008**, 93–109.
74. Nyholm, S. R. Education For Change. *J. Chem. Ed.* **1971**, *48*, 34.
75. Rinenart, H. W. Educating For Industry's Needs. *J. Chem. Ed.* **1947**, *24*, 386.
76. Bodner, G. M.; Domin, D. S. Mental Models: The Role Of Representations In Problem Solving In Chemistry. *University Chemistry Education* **2000**, *4*.
77. Popova, M.; Bretz, S. L. Organic Chemistry Students' Challenges With Coherence Formation Between Reactions And Reaction Coordinate Diagrams. *CERP* **2018**, *19*, 732–745.
78. Elby, A. Defining Personal Epistemology: A Response To And. *Journal Of The Learning Sciences* **2009**, *18*, 138–149.
79. Elby, A.; Hammer, D. Epistemological Resources And Framing: A Cognitive Framework For Helping Teachers Interpret And Respond To Their Students' Epistemologies. *Personal Epistemology In The Classroom: Theory, Research, And Implications For Practice* **2010**, *4*, 409–434.
80. Sandoval, W. A. In Defense Of Clarity In The Study Of Personal Epistemology. *Journal Of The Learning Sciences* **2009**, *18*, 150–161.
81. González, N.; Moll, L. C.; Amanti, C. *Funds Of Knowledge: Theorizing Practices In Households, Communities, And Classrooms*; Routledge: 2006
82. Moll, L. C.; Amanti, C.; Neff, D.; Gonzalez, N. Funds Of Knowledge For Teaching: Using A Qualitative Approach To Connect Homes And Classrooms. *Theory Into Practice* **1992**, *31*, 132–141.
83. Odden, T. O. B.; Russ, R. S. Defining Sensemaking: Bringing Clarity To A Fragmented Theoretical Construct. *Science Education* **2019**, *103*, 187–205.

84. Ferrell, B.; Barbera, J. Analysis Of Students' Self-Efficacy, Interest, And Effort Beliefs In General Chemistry. *CERP* **2015**, *16*, 318–337.
85. Ferrell, B.; Phillips, M. M.; Barbera, J. Connecting Achievement Motivation To Performance In General Chemistry. *CERP* **2016**, *17*, 1054–1066.
86. Vincent-Ruz, P.; Schunn, C. D. The Increasingly Important Role Of Science Competency Beliefs For Science Learning In Girls. *Journal Of Research In Science Teaching J Res Sci Teach* **2017**, *54*, 790–822.
87. Vincent-Ruz, P.; Binning, K.; Schunn, C. D.; Grabowski, J. The Effect Of Math Sat On Women's Chemistry Competency Beliefs. *CERP* **2018**, *19*, 342–351.
88. Hosbein, K. N.; Barbera, J. Alignment Of Theoretically Grounded Constructs For The Measurement Of Science And Chemistry Identity. *CERP* **2020**, *21* (1), 371–386.
89. Vincent-Ruz, P.; Schunn, C. D. The Nature Of Science Identity And Its Role As The Driver Of Student Choices. *International Journal Of STEM Education* **2018**, *5*, 48.
90. Vincent-Ruz, P.; Schunn, C. D. Identity Complexes And Science Identity In Early Secondary: Mono-Topical Or In Combination With Other Topical Identities. *Research In Science Education* **2019**, 1–22.
91. Greeno, J. G. On Claims That Answer The Wrong Questions. *Educational Researcher* **1997**, *26*, 5–17.
92. Hammer, D.; Elby, A.; Scherr, R. E.; Redish, E. F. Resources, Framing, And Transfer. *Transfer Of Learning From A Modern Multidisciplinary Perspective*, Information Age Publishing, 2005
93. Witherspoon, E. B.; Schunn, C. D.; Higashi, R. M.; Baehr, E. C. Gender, Interest, And Prior Experience Shape Opportunities To Learn Programming In Robotics Competitions. *International Journal Of STEM Education* **2016**, *3*, 18.
94. Ackerman, P. L.; Kanfer, R.; Beier, M. E. Trait Complex, Cognitive Ability, And Domain Knowledge Predictors Of Baccalaureate Success, Stem Persistence, And Gender Differences. *Journal Of Educational Psychology* **2013**, *105*, 911.
95. Vincent-Ruz, P.; Grabowski, J.; Schunn, C. D. The Impact Of Early Participation In Undergraduate Research Experiences On Multiple Measures Of Premed Path Success. *Scholarship And Practice Of Undergraduate Research* **2018**, *1*, 13–18.
96. Dorph, R.; Bathgate, M. E.; Schunn, C. D.; Cannady, M. A. When I Grow Up: The Relationship Of Science Learning Activation To Stem Career Preferences. *Int. J. Sci. Educ.* **2018**, *40*, 1034–1057.
97. Johnson, D. R. Campus Racial Climate Perceptions And Overall Sense Of Belonging Among Racially Diverse Women In Stem Majors. *Journal Of College Student Development* **2012**, *53*, 336–346.
98. Dortch, D.; Patel, C. Black Undergraduate Women And Their Sense Of Belonging In Stem At Predominantly White Institutions. *NASPA Journal About Women In Higher Education* **2017**, *10*, 202–215.
99. Glass, C. R.; Kociolek, E.; Wongtrirat, R.; Lynch, R. J.; Cong, S. Uneven Experiences: The Impact Of Student-Faculty Interactions On International Students' Sense Of Belonging. *Journal Of International Students* **2015**, *5*, 353–367.

100. Hausmann, L. R. M.; Schofield, J. W.; Woods, R. L. Sense Of Belonging As A Predictor Of Intentions To Persist Among African American And White First-Year College Students. *Research In Higher Education* **2007**, *48*, 803–839.
101. Master, A.; Meltzoff, A. N. Cultural Stereotypes And Sense Of Belonging Contribute To Gender Gaps In Stem. *International Journal Of Gender, Science And Technology* **2020**, *12*, 152–198.
102. Rainey, K.; Dancy, M.; Mickelson, R.; Stearns, E.; Moller, S. Race And Gender Differences In How Sense Of Belonging Influences Decisions To Major In Stem. *International Journal Of STEM Education* **2018**, *5*, 10.
103. Smith, J. L.; Lewis, K. L.; Hawthorne, L.; Hodges, S. D. When Trying Hard Isn't Natural: Women's Belonging With And Motivation For Male-Dominated Stem Fields As A Function Of Effort Expenditure Concerns. *Personality And Social Psychology Bulletin* **2013**, *39*, 131–143.
104. Strayhorn, T. L. Sense Of Belonging And African-American Student Success In Stem: Comparative Insights Between Men And Women. *Beyond Stock Stories And Folktales: African Americans' Paths To STEM Fields* Emerald Group Publishing Limited. 2011
105. Hammer, D.; Elby, A. On The Form Of A Personal Epistemology. *Personal Epistemology: The Psychology Of Beliefs About Knowledge And Knowing* Routlege, 2002
106. Altbach, P. G. The Imperial Tongue: English As The Dominating Academic Language. *The International Imperative In Higher Education* **2013**, 1–6.
107. Bransford, J. D.; Brown, A. L.; Cocking, R. R. *How People Learn*; Washington, Dc: National Academy Press: 2000.
108. Roblin, N. P.; Schunn, C.; Mckenney, S. What Are Critical Features Of Science Curriculum Materials That Impact Student And Teacher Outcomes. *Science Education* **2018**, *102*, 260–282.
109. Allen, C. D.; Penuel, W. R. Studying Teachers' Sensemaking To Investigate Teachers' Responses To Professional Development Focused On New Standards. *Journal Of Teacher Education* **2015**, *66*, 136–149.
110. Moon, A.; Gere, A. R.; Shultz, G. V. Writing In The Stem Classroom: Faculty Conceptions Of Writing And Its Role In The Undergraduate Classroom. *Science Education Sci. Ed.* **2018**, *102*, 1007–1028.
111. Conaway, W.; Bethune, S. Implicit Bias And First Name Stereotypes: What Are The Implications For Online Instruction? *Online Learning* **2015**, *19*, 162–178.
112. Jacoby-Senghor, D. S.; Sinclair, S.; Shelton, J. N. A Lesson In Bias: The Relationship Between Implicit Racial Bias And Performance In Pedagogical Contexts. *Journal Of Experimental Social Psychology* **2016**, *63*, 50–55.
113. Na, E. Do College Instructors Have Implicit Bias Toward Latino-Accented English Speakers? *Commission For International Adult Education* **2016**.
114. Bonilla-Silva, E. *Racism Without Racists: Color-Blind Racism And The Persistence Of Racial Inequality In The United States*; Rowman & Littlefield Publishers: 2006
115. Collins, P. H. *Black Feminist Thought: Knowledge, Consciousness, And The Politics Of Empowerment*; Routledge: 2002
116. Hunt, M. O. African American, Hispanic, And White Beliefs About Black/White Inequality, 1977-2004. *American Sociological Review* **2007**, *72*, 390–415.

117. Bang, M.; Warren, B.; Rosebery, A. S.; Medin, D. Desettling Expectations In Science Education. *Human Development* **2012**, *55*, 302–318.
118. Harper, S. R. An Anti-Deficit Achievement Framework For Research On Students Of Color In Stem. *New Directions For Institutional Research* **2010**, *2010*, 63–74.
119. Heppner, F. *Teaching The Large College Class: A Guidebook For Instructors With Multitudes*; John Wiley & Sons: 2007
120. Emdin, C. *For White Folks Who Teach In The Hood. And The Rest Of Y'all Too: Reality Pedagogy And Urban Education*; Beacon Press: 2016
121. Zhao, Y. From Deficiency To Strength: Shifting The Mindset About Education Inequality. *Journal Of Social Issues* **2016**, *72*, 720–739.
122. Teo, T. W.; Goh, M. T.; Yeo, L. W. Chemistry Education Research Trends: 2004–2013. *CERP* **2014**, *15*, 470–487.
123. Caspari, I.; Kranz, D.; Graulich, N. Resolving The Complexity Of Organic Chemistry Students' Reasoning Through The Lens Of A Mechanistic Framework. *CERP* **2018**, *19*, 1117–1141.
124. Grove, N. P.; Cooper, M. M.; Cox, E. L. Does Mechanistic Thinking Improve Student Success In Organic Chemistry. *J. Chem. Ed.* **2012**, *89*, 850–853.
125. Matz, R. L.; Fata-Hartley, C. L.; Posey, L. A.; Laverty, J. T.; Underwood, S. M.; Carmel, J. H.; Herrington, D. G.; Stowe, R. L.; Caballero, M. D.; Ebert-May, D.; Cooper, M. M. Evaluating The Extent Of A Large-Scale Transformation In Gateway Science Courses. *Science Advances* **2018**, *4*, Eaau0554.
126. Moon, A.; Moeller, R.; Gere, A. R.; Shultz, G. V. Application And Testing Of A Framework For Characterizing The Quality Of Scientific Reasoning In Chemistry Students' Writing On Ocean Acidification. *CERP* **2019**, *20*, 484–494.
127. Rodriguez, J.-M. G.; Towns, M. H. Research On Students' Understanding Of Michaelis-Menten Kinetics And Enzyme Inhibition: Implications For Instruction And Learning. *The Biophysicist* 2020, Purdue University (Doctoral Dissertation)
128. Underwood, S. M.; Posey, L. A.; Herrington, D. G.; Carmel, J. H.; Cooper, M. M. Adapting Assessment Tasks To Support Three-Dimensional Learning. *J. Chem. Educ.* **2018**, *95*, 207–217.
129. Bretz, S. L. Evidence For The Importance Of Laboratory Courses. **2019**. *J. Chem. Educ.* **2019**, *96* (2), 193–195.
130. Belland, B. R.; Walker, A. E.; Kim, N. J.; Lefler, M. Synthesizing Results From Empirical Research On Computer-Based Scaffolding In Stem Education: A Meta-Analysis. *Review Of Educ. Res.* **2017**, *87*, 309–344.
131. Vincent-Ruz, P.; Meyer, T.; Roe, S. G.; Schunn, C. D. Short-Term And Long-Term Effects Of Pogil In A Large-Enrollment General Chemistry Course. *J. Chem. Educ. J. Chem. Educ.* **2020**, *97*, 1228–1238.
132. Cho, K.; Schunn, C. D. Scaffolded Writing And Rewriting In The Discipline: A Web-Based Reciprocal Peer Review System. *Computers & Education* **2007**, *48*, 409–426.
133. Halim, A. S.; Finkenstaedt-Quinn, S. A.; Olsen, L. J.; Gere, A. R.; Shultz, G. V. Identifying And Remediating Student Misconceptions In Introductory Biology Via Writing-To-Learn Assignments And Peer Review. *CBE Life Sci. Educ.* **2018**, *17*, Ar28.

134. González, A.; Paoloni, P.-V. Perceived Autonomy-Support, Expectancy, Value, Metacognitive Strategies And Performance In Chemistry: A Structural Equation Model In Undergraduates. *CERP* **2015**, *16*, 640–653.
135. Ralph, V. R.; Lewis, S. E. Impact Of Representations In Assessments On Student Performance And Equity. *J. Chem. Educ.* **2020**, *97*, 603–615.
136. Kidman, J.; Abrams, E.; Mcrae, H. Imaginary Subjects: School Science, Indigenous Students, And Knowledge–Power Relations. *British Journal Of Sociology Of Education* **2011**, *32*, 203–220.
137. Hamel-Lambert, J. M.; Millesen, J. L.; Harter, L. M.; Slovak, K. Reflections On Community-Engaged Scholarship Faculty Development And Institutional Identity. *Journal Of Higher Education Outreach And Engagement (TEST)* **2012**, 129–148.
138. Kumar, A.; McCarthy, L. A.; Rehn, S. M.; Swearer, D. F.; Newell, R. N.; Gereta, S.; Villarreal, E.; Yazdi, S.; Ringe, E. Exploring Scientific Ideas In Informal Settings: Activities For Individuals With Visual Impairments. *J. Chem. Educ.* **2018**, *95*, 593–597.
139. Goodley, D.; Lawthom, R.; Liddiard, K.; Runswick-Cole, K. Provocations For Critical Disability Studies. *Disability & Society* **2019**, *34*, 972–997.
140. Neely, M. B. Using Technology And Other Assistive Strategies To Aid Students With Disabilities In Performing Chemistry Lab Tasks. *J. Chem. Educ.* **2007**, *84*, 1697.