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**What characterizes equitable and effective assessment and instructional practices
for EL students in the secondary STEM classroom?**

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May 15, 2022

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Abstract

English learners (ELs) need to be equipped with tools that can help them find success in their secondary school STEM classes, as well as for the world beyond high school. There is a delicate balance between making sure the curriculum provides all the necessary tools for later success, and also allowing students to use their linguistic and cultural diversity to enable their learning process. Thus, teachers must consider both effectiveness and equity in the design of their instruction and assessment. This literature review compiles the findings and research of educators seeking to provide better resources for content teachers with ELs in their classes. Effective instructional practices like visual aids, pre-teaching vocabulary and sentence frames can be used to help support EL students in meeting both language and content standards. Equitable classroom practices such as normalizing translation and translanguaging, incorporating culturally sustaining pedagogy, and encouraging inquiry-based student discussions all serve ELs' need for positive identity formation in STEM. Both how and when these practices are implemented are also considered. Suggested adaptations will vary across each specific unit, discipline and grade level, so it requires collaboration among language and content educators to figure out which strategies make the most sense in which contexts. Most importantly, these instructional modifications are framed as assets-based rather than deficit-based approaches. There is pedagogical value for *all* students, whether they are learning English for the first time, speak other languages at home, use different dialects of English, or are monolingual English speakers.

Who are English learners?

English learners (ELs) are often overlooked in the American education system. They are a growing population, accounting for 10.2% of public school students in 2018, up from 9.2 % in 2010, showing an increase in forty-two states. In terms of grade level, there is a gradual decline from about 15% in kindergarten to 5% in twelfth grade (National Center for Education Statistics, 2021). This is an alarming statistic because it shows that the retention rates for ELs is significantly lower than their peers, as they make up less of each subsequent class year. It could also mean that the older English learners are when they immigrate to the U.S., the less likely they are to enroll in school, and the more likely they are to pursue work instead. By locale, there are increasingly less EL students as population density decreases from urban to rural. Thus, there are more heavily concentrated areas of ELs in cities, and certain states, with the top five being California, Texas, New Mexico, Nevada, and Illinois. Spanish is by far the most common home language, accounting for 75.2% of all ELs, with Arabic, Chinese, English¹ and Vietnamese accounting for approximately 1 to 3 % each. Accordingly, this is where most ESOL (English as a Second or Other Language) programs, training and resources are focused. This makes sense, as it will benefit the most students, and ESOL trained teachers know specific places where their skills are especially needed. However, there are also many places that don't receive necessary ESOL support because they are not prioritized due to lower numbers, and this is usually in rural, very white areas. It can be especially difficult and isolating for ELs in these places because there are so few others like them, and most content teachers and advocates in the educational system don't have ESOL experience. Even when there are higher populations of immigrants and English learners, there can be a huge strain on the amount of trained professionals and resources. In both rural and suburban places, this leads to many content teachers being ill equipped to curate their instructional and assessment practices to best care and provide for English learners.

¹ This includes students who live in multilingual homes, where English is spoken at home in addition to other languages, or students who were adopted into English speaking families.

What are the barriers ELs face in a STEM classroom?

The content areas in Science, Technology, Engineering and Math (STEM) can be especially grueling for ELs because there is such a vast repertoire of content vocabulary required for each subject. Instruction and assessment usually not only rely on students' understanding of the English language, but expect them to understand specific terminology, which has little overlap in out-of-classroom contexts. This puts ELs at a disadvantage if assessment and instruction are not properly modified to align with their needs. Teachers need to incorporate learning standards into their lesson plans, and their subsequent assessments. Content teachers with ELs in their classroom need to consider both content and English language proficiency standards when designing their instruction and assessment. Most often, the language proficiency standards align to content standards to ensure that English learners are still progressing as their peers. "Moreover, the direction of this relationship suggests that the language to be learned needs to focus on the important STEM content and what is known about how children learn STEM content," (National Academies of Sciences, Engineering, and Medicine, 2018). This direction of alignment suggests that learning English in school is dependent on students' ability to pick up on academic language, which is very different from the more informal English that is required of students in social and everyday conversations.

Academic language has several definitions, but can be thought of as the implicit language that is expected of students in American schools in order to be taken seriously and to be considered "correct." This includes a more formal style of speaking and writing, proper grammar, clear pronunciation, cadence, and utilizes a wide range of vocabulary in different content areas. This is unrealistic to require of students in every context, especially if English is not their first language. In most cases, teachers do not directly evaluate students on these things, and assigning value to one's speech is usually an implicit bias. There is widespread systematic racism against certain types of literacies and oral communication that is considered informal, such as African American Vernacular English (AAVE), speaking with an accent, or using slang

terms A raciolinguistic lens recognizes that some people's voices are racialized by the "white gaze" because of how they sound or look (Paris & Alim, 2014). Assumptions are often made about their educational background or experience, just based on the way they speak. The "white gaze" does not necessarily mean a white person is perceiving others who are not white; it refers to the general societal idea that prioritizes academic English over other dialects or languages (Flores and Rosa, 2015).

The idea of academic language is not necessarily bad, especially when it allows people to use content language to describe processes and events more specifically with others who have studied that discipline. However, when it becomes a gatekeeping device to keep certain people out of academic circles, schools or careers, it can become a huge problem. For English learners, academic language is often used as a connection between language proficiency and specific content knowledge, based on how the standards are set up. In the 1980s, Jim Cummins made the distinction between basic interpersonal communicative skills (BICS) and cognitive academic language proficiency (CALP). BICS refers to conversational, social language used in day-to-day interactions, and usually develops for ELs within a few years. However, CALP refers to the linguistic ability to comprehend and communicate in more cognitively demanding ways without context, as is often required in classroom settings (Cummins, 1985). This is estimated to take between five and seven years for ELs to obtain the same level of proficiency as their non-EL peers, which is significantly different from BICS. This type of academic language is another barrier for English learners in the American classroom. Not only do they need to learn a new language, apply it in everyday life situations and be able to communicate with their peers and teachers, but they also have to learn specific vocabulary and phrases for each discipline. While all students have to learn new vocabulary, English learners are put at a disadvantage without accommodations because they may not have been exposed to any of the words before, and won't necessarily know certain root words or mnemonic devices that make them easier to remember for English speakers.

There is a real need to make sure that the support provided for English learners aligns with their needs, so that they have the best chance at fulfilling language proficiency standards and the same content standards as their peers. Equity and effectiveness are both important categories to consider when deciding how to modify or differentiate instructional and assessment practices. In order to motivate and encourage ELs to come to and stay in school as they get older, they need to feel like they belong and their identities are valued in the classroom through equitable teaching practices. At the same time, they should learn all the tools they need to be successful in higher education, so they can know that there are many future pathways open to them, which is characterized by effective teaching practices. Effectiveness can be measured by how well ELs learn content standards in relation to their peers, and equity can be measured by how much ELs feel like they belong in the classroom.

Assessment and instruction in STEM content classrooms can be made more effective for ELs by preparing students as best as possible to meet content standards. Based on a review of the literature, this includes using visual representations of concepts, using sentence frames and other forms of scaffolding for written and oral work, and explicitly teaching vocabulary ahead of time to acknowledge the linguistic load in science and math subjects. Assessment and instruction can be made more equitable by making sure students feel like they belong in the classroom, and that their cultural and linguistic backgrounds are valued. This could include incorporating translation and translanguaging practices, expanded cultural representations in problems, lessons and discussions, as well as critical discourse and inquiry around content areas. This allows for more representation in content knowledge, and allows students to see positive examples of this content relating to their language and culture, and teaches them to be critical thinkers about how and what information is presented. Critical discourse also allows teachers to get feedback on their lessons and can give them insight on what to change in the future. As students increase their language proficiency, some supports that address effectiveness can slowly be taken away, as they catch up to their peers in their English repertoires. They will become increasingly comfortable in monolingual English and academic language focused environments, which they will continue to

encounter. However, supports that address equity should be continued to be implemented wherever possible because even as an EL's language proficiency improves, they won't lose their other language and cultural knowledge. It will remain a deep and central part of their identity which should be honored and respected throughout their education.

Case Studies

As a way to humanize the experiences of English learners, I decided to include two student portraits to ground this literature review of instructional practices suggested for STEM content teachers. These case studies are based on students that I have worked with in my previous education field placements. Though some information is fictitious, I've chosen to use pseudonyms lest they bear any resemblance to the original students. Their different goals illustrate that each student is unique, and that teachers need to take into account each individual student needs when deciding how to modify instruction.

Natali is in twelfth grade at a school in North Philadelphia. She recently immigrated from the Dominican Republic to finish her schooling. She attended private school in her home country and left in the middle of her senior year. Because of this, she has to repeat her entire last year of high school in the United States in order to get a diploma. She wants to pursue higher education to become a nurse. She is very interested in biology and chemistry, but isn't sure her good performance from school in the Dominican will transfer to the American classroom. Having Spanish as her primary language, Natali is the only student in her class to be placed into ESOL 1 - a course for emergent bilinguals who scored between a 1 and 2 on the WIDA Language Assessment. Although she is a beginner in English, her teacher notes that her English listening comprehension is decent, and she is fully fluent in Spanish – both conversational and academic. How can instruction and assessment be modified to ensure that Natali can finish her last year of high school, but first year in the United States? How can assessment be made the most effective, so that Natali can advance to further schooling with as much English skills as possible?

Kareem is in eleventh grade and in a high school chemistry class in Central Philadelphia. He has lived in the city ever since he can remember, but his parents immigrated from Nigeria a few years before he was born. English is his primary language, though he knows some conversational Yoruba that he picked up from his parents, who are fully bilingual in English and Yoruba. He code switches frequently between academic English and African American Vernacular English (AAVE) depending on whether he's talking to friends or teachers. He really wants to leave the city after high school, but feels obligated to stay to help with his father's business, a convenience store. He was held back his ninth grade year because he did not pass English or Social Studies, so many of his friends are in the class year above him and are almost ready to graduate. He used to really enjoy his science and math classes, and excelled in middle school. But ever since he got held back, he lost motivation to put effort into most of his classes, and is in danger of falling behind again. This is the last science class he has to take in order to graduate, and he just wants to get it over with. How can instruction and assessment be made the most equitable, so that Kareem has the chance to be successful? How could assessments be structured so that he might regain interest in science, and become motivated again?

Both students can benefit from modified instruction and assessment. Though Natali is officially labeled as an English learner, Kareem grew up in a bilingual home, and therefore also has a wider communicative repertoire than his monolingual peers. Tapping into the linguistic diversity of both these students has a great potential to encourage and motivate them in their STEM classes. They have different goals after high school, but the goal of education is to make sure that they do not feel that their options are limited due to external factors. In order to curate instruction and assessment to be the most beneficial to them, there needs to be a focus on both effectiveness and equity. If students are comfortable in the classroom, but don't learn the skills for higher education or the workplace, how will they be prepared for beyond high school? And if they are taught appropriate academic language and content-based skills, but don't feel like they belong in the classroom, how are they expected to stay motivated and feel supported?

Addressing Effectiveness Through Skill-Based Needs

In our current public school system, there are sets of standards for every discipline that teachers need to build their lesson plans around. In order for students to advance and to be considered to be knowledgeable about a particular unit, they must demonstrate what they've learned through assessment. These standards are made with the intention of equalizing the education experiences of students in different schools and in different places. The hope is that when they come together in the workplace or in higher education, that they will have been prepared similarly, so that they can move forward together at the same rate, and with the same amount of effort. Of course, this isn't the case because it is impossible to completely level the playing field for everyone. And if the standards were developed with a particular type of student in mind, it becomes harder to provide "equal" experiences in secondary school. Everyone has different background knowledge, and access to different resources outside of the classroom. This means that it is necessary to provide more scaffolding, guidance, and structure, especially for lower language levels. Lisa Delpit (1988) proposed that in order for people to be able to participate in "a culture of power," they needed to be explicitly told the rules of that culture, which in this case is the vocabulary, grammar, structure and discipline specific rules in academic English. Students need to be taught standards and skills that will be useful to them beyond the secondary school classroom, so that they have the best chance of being as prepared as their peers. But they should be given chances to reflect and critique on the standards and skills being taught in the classroom. In addition to teaching the standards and skills as they exist, teachers should devote time and energy to making sure their explicit and implicit curriculum allows for multiple literacies and utilizes students' different cultural and linguistic repertoires, while questioning the systems of power as they exist (Flores and Rosa, 2015).

Three seemingly axiomatic strategies for English language instruction include visual aids, sentence frames and scaffolding, and pre-teaching subject specific vocabulary. These strategies have been in use for many years, and recent literature seeks to connect the purposes of these instructional practices

to contemporary practices, rather than falling back on the traditional understanding of language acquisition for English learners (Grapin et al, 2020). It is important to consider both *how* and *when* these strategies are implemented, rather than throwing them out completely because they all can be helpful tools with the right framework. There has been a notable shift in national science education standards towards “knowledge-in-use,” or connecting content with actual scientific practices, where students need to be able to develop “well organized knowledge networks that allow them to activate and connect sets of relevant ideas across contexts,” (Kubsch 2019). This includes engagement with disciplinarians of that work (i.e. mathematicians and scientists) in posing hypotheses, engaging in analytical discourse (arguing from evidence) and answering questions about natural phenomena across disciplines rather than instruction that focuses on learning discrete facts and information. Similarly, there has also been a shift in language education towards “language-in-use,” which is more purposeful communication in social contexts and views language as a “product of interaction and learning” rather than discrete elements of vocabulary and grammar in a “fixed sequence,” (Grapin et al). These contemporary perspectives in content and language education compliment each other, however, the instructional strategies used with ELs are more often modeled after traditional thinking, especially “in the case of content area instruction... which requires integrating theoretical perspectives from both content area education and language education in a principled manner.” In Grapin et al (2020), the research team compiled results from a study of a yearlong fifth grade science curriculum, which had been developed over a period of four years. They identified three separate categories for each instructional practice that was studied: how it has been used with ELs in the content areas, tension that arose in light of contemporary perspectives in both content and language learning, and proposed adaptations to resolve these tensions.

Exploring the pedagogical value of visuals

Employing visual aids and tangible representations of concepts is a simple and relatively easy way to modify instruction and assessments to be more inclusive of English learners. Using graphs, tables,

diagrams and pictures is already common, especially in science curriculum, as data and results are often represented in a visual format. It is important that English learners do not have to solely rely on text to learn new information. While it is the goal for English learners to be able to read at the same level as their peers, learning new concepts and STEM knowledge should not rely on the extra linguistic task of reading heavy amounts of text. Grapin et. al (2020) defines visual aids as “pictures, charts, and realia that assist ELs in comprehending or producing language.” Teachers can either provide visual aids as a supplement to reading a text, or they can allow students to express their understanding through pictorial representations rather than through written language. Tensions arise when teachers treat visuals only as supplements to “real and accepted forms of information.” However, from a knowledge-in-use perspective, visuals are not just language scaffolds, but are “essential meaning-making resources of disciplinary communities,” (Lemke, 1990). Too often, visuals are treated as if they are only useful to ELs after they’ve developed proficiency in “more privileged linguistic modalities,” such as written or spoken language. If teachers treat visual aids as their own entity, or having meaning-making in and of themselves, then it expands students’ communicative linguistic modalities. For example, pictures and diagrams can provide spatial information that could not be as accurately explained in text, and allows students to understand a concept more fully.

There are multiple representations that can mediate students’ interpretations of data and concepts. Graphs and diagrams are commonly used in biology, chemistry, physics, engineering and math classrooms to demonstrate relationships between variables and to show how to derive important equations based on their relationship to each other. Another study showed how eighth grade bilingual students interact with several conceptual models to understand the laws of physical motion and mathematical relationships (Moschkovich et al, 2017). They used graphs, written questions, written responses and oral discussions as different measures of the students’ understanding of velocity and acceleration, which are important foundational variables that can be used in higher level equations. They were asked a series of questions about a distance over time graph describing a biker’s trip with a variety of changing and

constant slopes. First, they were asked to tell a story about what was happening to the biker, using informal language with their partner, in which language they were most comfortable using. Then, they were asked qualitative questions to see when the biker was moving the fastest, slowest, or not at all. Finally, they were asked more specific quantitative questions about particular graph segments. Students were encouraged to use multiple semiotic resources including oral language, written text, mathematical symbols, and gestures in addition to the visual graphs. Though it was easy for students to read particular values from the graph, they had trouble articulating how data points were physically related to each other (Moschkovich et al). Overall, having a visual representation of what happened over time allowed the students to discuss their interpretations and claims based on the evidence directly in front of them. Though it was challenging work, the students' oral discussions around the visual representations of data gave their teachers more information about their understanding than from just reading their written responses. Ultimately, this data suggests that mathematical literacy cannot only rely on written work because there is valuable information for both students and teachers from using visuals.

There have been few studies specifically focused on low-literacy, newcomer ELs and their science attitudes. And since many studies also focus on ELs in elementary school, it discounts a growing population of newcomers who arrive as teenagers (Allard, 2015). They may have a strong content knowledge background, but this is often not recognized if their English proficiency skills are lacking. So, it is especially important to consider how instructional practices can be adapted to help them. Tretter et al. (2019) explore how newcomers' positive attitudes towards science can be strengthened through visually enriched science and language instruction. Visually-rich media not only lowers language barriers for ELs, but it also is being increasingly used to build scientists' virtual and interactive worlds to record direct observations and authentic data, such as with simulations and maps (Tretter et al, 2015). These interactive visual tools can be extremely useful for both ELs and non-ELs, because it allows students to better understand spatial and temporal contexts of a particular phenomenon. In Tretter et al's study (2019), they incorporated regular planetarium viewing sessions with primarily newcomer middle school Earth science

students. This included video footage “flights” through 3-D data of places on Earth and in the solar system, short video clip documentaries, and dynamic animations of otherwise unobservable phenomena. They collected data on students’ self-reported science interest levels, and found that over the course of half a year, students’ attitudes towards science had significantly increased by the midpoint, but remained stagnant and even decreased a little by the end. They partially attribute this fact to more newcomer students coming in during the study, and because some of the class material got more difficult, this could have influenced students’ overall opinions. Finally, Tretter et al. (2019) also point out that with the visuals studied, they didn’t detract from the amount of material that was able to be covered, or add to the amount of time needed for students to retain information about vocabulary, concepts and ideas.

A proposed adaptation is to center visuals as key parts of students’ conceptual understanding, rather than only using them as temporary scaffolds. While building visual models is especially helpful for ELs, it is beneficial for everyone because it allows students to engage in scientific practices with multiple linguistic modalities. This also encourages an asset perspective of visual learning, rather than only seeing it from a deficit point of view, or a form of remediation. In Grapin et al’s study (2020) of the fifth grade science curriculum about consumption and waste, spoken and written communication allowed the students to discuss the cause-effect relationship between gas particles and being able to detect a smell, but the use of pictorial diagrams allowed students to develop a spatial awareness of how gas particles actually move across the room over time through diffusion. Having physical models for students to manipulate allows them to change and understand the relationship between different variables more easily.

The value of context-embedded vocabulary

Pre-teaching vocabulary is another long-standing technique used in content instruction for ELs. Also known as frontloading, this includes introducing general and content-specific vocabulary that is essential for the upcoming unit (Grapin et al, 2020). The goal is to help ELs become more familiar with words before they are used in lessons, so there is less linguistic demand and they can focus on the new

content instead. However, there is tension because this may limit opportunities to develop a deeper and more meaningful connection between words and related concepts when they are situated within the context of a lesson. When vocabulary words are decontextualized, they can also “reinforce a simplified view of communication in the content areas that privileges lexical aspects of language,” (Grapin et al). Having a growing vocabulary list for students to be able to reference is still a good practice, and the teacher can continually add to it as they come across new words in the curriculum. Vocabulary should not be treated “as an end in itself but as a means to achieving disciplinary ends,” (Grapin et al), which indicates that vocabulary can be a useful pedagogical tool that compliments conceptual understanding, rather than completely preceding it.

Grapin et al. (2020) further suggests that teachers refrain from explicitly introducing vocabulary words until students have grappled with and come to some understanding of the relevant scientific ideas. This can further help with their sense-making, and prepares them to answer more in-depth questions about the concept based on their own conclusions, rather than only regurgitating memorized definitions. The danger is putting too much value on memorization, and not allowing students the time to develop their own understanding. In the fifth grade science classroom, the teacher demonstrated a tangible example of smell, as food was allowed to decompose in bottles over time. Eventually, an unpleasant smell developed, which students could actually sense with their noses. They were also prompted to take measurements of the bottle weight before and after the observed changes. All of these activities allowed students to come to their own conclusions about what “smell” really is, but also backed up the idea that a smell has to start from somewhere. Then when students were asked if the amount of matter in the bottle had changed, they could support the claim that the “smell” escaped the bottle in the form of gas particles with evidence in the form of observations and collected data.

A study that combined a curriculum with purposeful planning and innovative academic vocabulary instruction was used to help fifth grade Hispanic ELs as they prepared for high stakes

standardized science tests (Jackson et al, 2020). They recognized that many teachers in previous EL science achievement studies failed to engage students in argumentation and inquiry practices, as required by the the Next Generation Science Standards and on standardized tests (Lee et al, 2008). Learning vocabulary words is crucial to be able to make scientific explanations, and to continue learning new material because content-specific words come up frequently. ELs therefore need classroom opportunities to practice using these words, so they will grow more comfortable using them for speaking and writing assessments. It is more impactful for students to learn vocabulary words by having them actively engage with their meaning in some way, rather than just learning their definitions (McKeown & Beck, 2014). And this requires teachers being able to simultaneously curate lesson plans with language and content learning goals - for both ELs and non-ELs. A practical example explored by Jackson et al. (2020) are word walls, which allow students to interact with and build upon the definition of a given vocabulary word. While it is scaffolded by the teacher, everyone can add to it with drawings, sticky notes, print-outs, etc and students can learn from each other, rather than just accept one formal definition. At the high school level, this could be easily implemented by having a list of relevant vocabulary words on posters or a whiteboard that students or the teacher could add to at the end of every lesson. Additionally, some vocabulary words could be introduced through teacher demonstrations or student-led experiments, and then reinforced with written and spoken explanations.

When does sentence scaffolding make sense?

Sentence stems, such as frames, sentence starters and other scaffolding techniques for both spoken and written language are other important and long-standing techniques used with ELs. The concept of sentence scaffolding comes from Vygotsky's sociocultural theory from 1962, "in which a more knowledgeable other creates conditions that make it possible for a learner to take part in a learning activity and expand what [they] currently know and do," (Rodriguez-Mojica et al, 2018). Often, partial sentence phrases or fill-in-the-blank prompts are used with ELs to lower the barrier for them to be able to participate in conversations or written assignments, especially if they don't have all of the required

language knowledge. Sentence stems serve as instructional scaffolds because they model the expected language use for the specific task. They can jump-start students' memories to get them started, without fully giving them the answer. Another benefit is that students can be exposed to chunks of text that they can later use independently (Grapin et al, 2020). They serve as entry points into discussion to alleviate some cognitive load, allowing students to focus primarily on the content, rather than on the phrasing. Not all students need sentence stems, but it can be helpful to offer to all EL and non-EL students, and they can decide whether to use them or not (Rodriguez-Mojica et al, 2018).

However, sentence frames can be detrimental if not used properly or with intent. Because they are meant to be scaffolds that prepare students for further language use, if the responsibility is not gradually transferred to the student, then they may become overly reliant on them. Secondly, if teachers do not have a specific purpose or type of information they are eliciting in mind, they may prove confusing for students. For example, if the sentence prompt does not match the expected language function, then students may learn responses that don't match the context. And it is also important to recognize when students might address a language objective and standard, even if they don't follow the sentence stem exactly (Rodriguez-Mojica et al, 2018). Another tension that arises from using sentence stems is that it paints language as a discrete structure and formulaic in nature. It restricts student choice, limits the range of answers and discourages spontaneous, off-script language contributions that students might be able to come up with on their own, if given free reign. And because sentence frames and starters may prompt students to think about a certain set of vocabulary, it also disregards students' funds-of-knowledge from their homes and communities (Gonzalez, Moll & Amanti, 2005).

In consideration of contemporary perspectives, teachers should avoid using sentence frames and starters too early in the learning process of new content, so that students can still make diverse and open-ended observations. Then, they can be used once students are ready to summarize what they have learned in a more polished form. They can even be structured in a way that helps engage students in the

“scientific disciplinary practice of an argument,” such as identifying claims, evidence and reasoning when presenting scientific information and research (Grapin et. al, 2020). However, these scaffolds should eventually be removed from instruction as students become more proficient with the vocabulary. As an example in the fifth grade science classroom, students were allowed to make observations about decomposing food materials by saying whatever came to their minds. This prompted them to comment on whatever they found the most interesting, rather than only filling in the blanks of a scientific claim such as, “The food was in the form of _____, but now is in the form of _____.” This led to several creative student responses: “Something is coming out!” and “The ghost of the banana is leaving,” which actually led the class through a discussion that ended in the consensus that the solid banana decomposed and changed its form into something else, which is an important take-away about the solid and liquid states, as well as the law of the conservation of matter (Grapin et al). This can be modified for the secondary STEM classroom where the teacher encourages more open-ended responses in class discussions when concepts are initially taught, and during some individually assigned classwork. That way students can approach the content in whatever makes the most sense to them. Sentence frames could still be provided at least in the beginning stages, especially for class discussions, but students should be encouraged to use whatever comes to their mind first. Then when it comes time to more formally summarize ideas in homework assignments, quizzes and exams, sentence scaffolds can be especially helpful.

Addressing Equity By Instilling Feelings of Belonging

Effectiveness, as defined by academic achievement, and equity, as defined by positive identity formation, do not have to be at odds with each other. In fact, teachers, policymakers and everyone involved in education need to consider these two categories together because of how they are intrinsically linked. Social and group identities, such as being categorized as an English learner or a speaker of non-standard English, affect achievement and student’s motivation and ability to reach academic standards. Salient social identities can “trigger psychological threat and belonging concerns and how

these produce persistent performance decrements, which through feedback loops can increase over time,” (Cohen and Garcia, 2008). Stereotype threat is defined as the fear of confirming a negative stereotype about one’s group (Steele & Aronson, 1995). Identity can be psychologically engaged if one believes that a particular situation could be linked to an aspect of their social identity to a negative outcome. Academic performance therefore suffers if people think that this threat surpasses their ability, as defined by the stereotype, or desire to overcome it. But prior studies have shown that if there are resources available that encourage students to overcome the challenge, such as identifying with one’s social group in that situation, this offsets the threat and performance can be maintained or improved (Cohen and Garcia, 2005). So, while the focus on meeting standards can be a measure of student academic success, identity formation and feelings of belonging can also directly affect a student's performance.

Additionally, it is important to recognize the goals of education. For some students, their goal may be higher education, while for others, it may just be to find a suitable job in the workforce. Stephen Gorard (2018) gives the following proposition about the purpose of education:

“Education prepares people for the world of work, or for more education. It socializes them into society or gives them skills for life. It provides them with a general knowledge about the world. And it keeps young children secure and engaged while their parents work. However, one of the main reasons that initial education is free, compulsory, universal and state-regulated in most countries is so that what, and how much, children learn is not just determined by their family circumstances. Education up to a certain level is one of the guaranteed rights for all children and young people in a civilized society.” (pg. 5)

All states in the U.S. have educational standards in place to try to make sure that all students have the same background knowledge when it comes time to leave secondary education. The expectation of educational standards is meant to increase equity among students in school, so that their education is not just defined by their family’s resources and availability. At the same time, this is a rather limited view of education because despite schools seeking to make circumstances more equitable for students, there are

still so many limitations for students with minoritized identities. There are still great achievement gaps in socioeconomic status because of what the people at the top can afford via time and resources. And most standards and curriculum designed to meet those standards are created with the average middle-class white English speaking student in mind, even though the demographics of the American education system are rapidly becoming more diverse.

Gorard (2018) goes on to discuss how educational policy makers should not base their work just on the evidence of students meeting standards and performing better on standardized tests if the achievement gap is also increasing.

“Evidence cannot and should not determine education policy. It should simply help to inform policy-making... For example, the most secure evidence might suggest that a particular education policy would increase the average attainment of students but also increase the average difference between high and low attainers. If raising average attainment is paramount, the policy could be deemed a success. But if making the system fairer is a priority, the policy may be a failure (although... raising attainment overall and reducing attainment gaps are not necessarily in tension).” (pg. 4)

If the goal of education is to make conditions more fair for all students, regardless of their linguistic and cultural background, then more work needs to be done to not only increase English learners' academic performance, but to increase their positive identity formation in the classroom. While science and math content standards still need to be taken into account when planning STEM instruction for ELs, there should be just as much planning and instructional practices devoted to promoting equity for all students, and by showing that their cultural and linguistic identities are valued in the process of learning. Teachers should explain to their students why standards are put into place, and how meeting them can help students be best prepared for life beyond secondary education. But they also should encourage their students to be critical of standards and curriculum, especially if they feel it doesn't properly value all of their background knowledge and skill sets that they bring. Teachers should provide the space for their students

to develop their own educational goals as well, which can be promoted for ELs especially with frameworks and practices like culturally relevant curricula, translation and translanguaging, and content-area critical discourse.

The power of language choice: translation and translanguaging

Teachers can use both translation and the related practice of translanguaging to give students the space to express themselves and their learning process other than in only English. Translanguaging expands the definition of bilingual speech beyond the language use itself and contextualizes it from bilingual speakers' own perspectives. More specifically, translanguaging encompasses “multiple discursive practices in which bilinguals engage in order to make sense of their bilingual worlds,” (Garcia, 2009, pg. 46). Though different, translanguaging can be understood as a type of code switching when speakers of multiple languages must decide which is most appropriate to use in which contexts. This also includes all non-standard English modes of communication and linguistic repertoires. While translation refers to specific transactional language exchanges, translanguaging positions all language exchanges as valid and useful in the learning process, and doesn't favor one language over the other (Garcia, 2009).

Garza (2017) explores how translanguaging can be used in the teaching and learning practices of a bilingual seventh grade math classroom. The two main takeaways were that translanguaging can be used as a pedagogical tool to help students better grasp mathematical meanings, and that it allows a greater fluidity and movement in both the teaching and learning process. In the classroom that was focused on, the teacher and his students would frequently switch between languages when providing information or asking questions. The teacher did not show a preference for one language over the other, and his model of translanguaging, sometimes mid-sentence, encouraged his students to participate more fully because they knew both Spanish and English were equally accepted in the classroom. Lessons also ran smoothly because they did not have to stop to clarify linguistic meanings as they could use languages interchangeably. They will eventually have to grasp mathematical ideas in English, but allowing them to

use their home language in the classroom makes them feel more comfortable. To know how one thinks and speaks most naturally is considered an acceptable way to learn also adds to ELs' positive identity formation when learning that content.

Even if the teacher doesn't speak or understand the same languages as their students, they can provide assignments or activities where students are encouraged to speak in whatever language they are most confident with. For written assignments, the teacher can use translation software so that they have a better idea of their students' conceptual understanding. It is important to make sure there are clear expectations about English language use because it is usually the language of assessment. This is not to be punitive or make things more difficult for students, but so that they can be better prepared. As a baseline, providing the space and acknowledging that it is acceptable to learn and think in one's original language is a way to validate diverse linguistic backgrounds. If appropriate and students are willing, they can also teach their teacher and peers words related to the concepts in class.

Utilizing students' diverse cultural and linguistic backgrounds

Culturally relevant curricula was a term first coined by Gloria Ladson-Billings as a "theoretical model that not only addresses student achievement but also helps students to accept and affirm their cultural identity while developing critical perspectives that challenge inequities that schools (and other institutions) perpetuate." (1995, p. 469) Ladson-Billings wanted to redefine student achievement and challenge deficit views of African-American students. She wanted to empower both students and teachers to question the nature of teacher-student relationships and to understand how the multiple identities we bring into the classroom affect how we learn and interact with others (Mensah, 2021). In her seminal work, *The Dreamkeepers* (2009), Ladson-Billings separated this framework into three domains: cultural competence, student learning and achievement, and critical consciousness. Teachers need to be willing to learn from their students and need to be prepared to learn competence outside their subject area as well. Students need to be held accountable for learning content standards, while valuing different perspectives

and respecting cultures different from their own. And curricula need to encourage students and teachers to be critical thinkers in all areas, whether they are thinking about new scientific concepts or thinking about how it applies to their lives.

Over the years, this framework was built upon, and new authors came up with a culturally responsive framework where students and teachers are further challenged to respond to people's different cultural identities and come up with ways to address social inequities, rather than only learning about them. Geneva Gay explains that this framework is both *routine* because "it filters curriculum content and teaching strategies through their cultural frames of reference to make the content more personally meaningful and easier to master" for traditionally marginalized groups (something that has always been done for middle-class white English speaking students) and *radical* because "it makes explicit the previously implicit role of culture in teaching and learning, and it insists that educational institutions accept the legitimacy and viability of ethnic-group cultures in improving learning outcomes," (Gay, 2010). This framework elevates linguistic and cultural knowledge as intrinsically valuable and something that needs to be given clear time and attention in the classroom, no matter the subject area. In fact, acknowledging that it can improve learning outcomes rather than just being an additional resource is crucial for teachers to understand. Some of the proposed adjectives for learning outcomes are: validating, comprehensive, multidimensional, empowering, transformative and emancipatory (Mensah, 2021).

Then, most recently, culturally sustaining pedagogy (Paris and Alim, 2017) has been at the helm of these asset-based educational frameworks because it especially seeks to uplift marginalized cultures, and preserve and continue building what they have and acknowledging their dynamic nature, rather than only treating them as relics of the past. It seeks to not only affirm and connect to students' cultural backgrounds, but to sustain this connection throughout education. It encourages students to be active critiquers of dominant power structures. Some of the main features discussed by Paris and Alim include valuing community languages, practices and ways of being by centering multiple languages, literacies in

the classroom, rather than only thinking of them as “add-ons.” Schools are also implored to be accountable to their surrounding communities by continually involving community members in conversation about what they most value and want to sustain. It also calls for a curriculum that is intentional about connecting present learning to the histories of surrounding racial, ethnic and linguistic communities - both on the local and national scale. And finally, it balances the need to sustain minoritized cultural and linguistic practices, while also providing access to the dominant culture of white, middle-class and standard American English (California Department of Education, 2022).

A practical suggestion for teachers is to be more aware of how cultural norms are reproduced in their curricula. If only the dominant culture is encouraged and if minoritized cultures are either absent or even looked down upon, English learners with multiple linguistic and cultural assets will struggle to see how they are valued in the classroom. Even something as seemingly simple as the examples and words used in mathematical word problems can affect how students think about themselves. They may not understand traditional American references to things like sports, different types of measurement, expensive vacations, etc and may be led astray from the content objective. What often is painted as “normal” actually represents a mismatch from many EL students’ lived experiences, and over time, can build up tensions about whether they really belong in that classroom space (Bright 2017). Whereas, “students with dominant-culture identities can, in many cases, nest comfortably into school and find confirmation and validation of their worlds, with the flexibility and perhaps desire to appropriate additional concepts and practices that will provide further privilege,” (Bright). This paper also makes the claim that texts are under the most scrutiny in social studies and language arts classrooms rather than in STEM classrooms, because people assume that science and math are less likely to be areas where cultural norms are talked about and perpetuated. However, there is still a “hidden curriculum” at play (Jackson, 1968) where there is an unwritten and unspecified transmission of cultural norms, values and beliefs through all educational content and social interactions. Even something as subtle as evaluating judgements about social conditions, or offering an incomplete view of events can set a tone for the

intolerance of people's identities and backgrounds. And unfortunately, the shift to include more ethnic names and pictures of more diverse people in textbooks, as an example, borders on tokenism if it is not matched with action and movement away from the status quo in the classroom and other social spaces (Bright). Teachers are thus encouraged to think about several things when they are designing or choosing which word problems to use in a STEM word problem: "What is valued in this problem? Who or what has power? Does this problem contain or promote 'aspirational' cultural values?" i.e. implying that the student should know something besides the elicited content knowledge (Bright). If teachers consciously consider these questions, and keep their student populations in mind, ELs will feel more confident in solving word problems involving their own knowledge and seeing themselves positioned as valued learners.

Inquiry learning and student-run content discussions

Researchers and educators have long advocated for linguistically-rich content-area experiences, including inquiry-based learning and student-led discussions as a way to interest more ELs in the sciences (Amaral, 2002). Inquiry-based learning triggers students' curiosity and puts them in the driver's seat when it comes to formulating their own questions about new concepts. Instead of teachers only delivering information to teach new concepts, students are given time to think and discuss their questions with each other based on some preliminary information, rather than it being revealed all at once. This can especially benefit ELs because it gives them time to build context, common experiences with other students, thinking skills, cooperative learning, comfort level and positive attitudes (Amaral, 2002). Even though this study focused on elementary school students, there is still valuable information that can be adapted for use with secondary school students.

Amaral et al (2002) encourages teachers to give their students manipulatives that allow them to build context through exploring materials with multiple senses, such as with sight, touch and sound. However, when designed appropriately for secondary school students, manipulatives can still be very

helpful and lead to productive discussions with other students when deciding how to arrange certain objects. Students also need to be given more time to think on their own first, which allows them to utilize both their most fluent language and English in building their conceptual frameworks. Then inquiry-based discussions can build common experiences for all students, regardless of proficiency level, at least in terms of utilizing observation and exploration and increasing the chance of learning from each other. ELs may still feel a barrier to participating at the same level as their non-EL peers in discussions, but if they are encouraged to speak in those casual speech environments, they will become more comfortable over time. And it decreases the reliance on individuals' reading of texts, which necessitates the higher cognitive task of comprehending academic language. Inquiry-based materials and discussions encourage peer collaboration, which increases the likelihood of casual questions, and students sharing their perspectives and knowledge with each other, such as serving as a translator for a particular activity or explaining a concept in simpler terms. Working as a team also lessens the pressure placed on students to feel like they need to come up with the "correct" answer the first time. If all ideas are posed as hypotheses, then they are treated as equally valuable and can build off of each other. And it is often true that there isn't necessarily one "correct" answer or approach to solving problems. Finally, inquiry-based discussions can be especially effective at increasing students' positive attitudes because figuring out one step of the process together motivates students to want to keep figuring out the rest of the steps (Amaral et al).

Too often, high school EL students' low performance in math is attributed to their low linguistic proficiency and status. However, two main factors that inform math performance are students' instructional experiences and math placement, both of which have been shown to be affected by linguistic tracking, in addition to racial, social class and gendered tracking (Mosqueda, 2013). This means that EL's math performance can potentially be improved by addressing these two intermediary factors: greater access to higher level coursework and placement, as well as access to a greater set of instructional experiences. Callahan et al (2020) research how content-area discussions could improve EL's math

performance. This study categorized students based on whether they were at-or-above grade level, or if they were below grade level. Regardless of linguistic status and course level placement, there was a positive association between the tenth graders' self-reported participation in student-led math discussions and their GPAs. However, only in low-level placement classes did ELs report a higher or comparable participation rate as their non-EL peers. ELs were much less likely to participate than their non-EL peers in higher level class placements. This suggests that student discussions in class may help balance out the limiting nature of low-level placements, but that instructional experiences alone, such as encouraging student-led discussions, are not enough to improve overall academic performance of ELs to the same level as their non-EL peers. Schools need to also address the overrepresentation of ELs in low-level coursework (Callahan et al, 2020). While this study suggests that real change cannot occur if larger scale educational policy and smaller scale classroom practices are not working in tandem, I still argue that teachers should take this information to heart to improve their EL students' overall interest and potentially performance.

Incorporating student-led discussions with mixed classrooms of ELs and non-ELs can be tricky, especially if non-EL students dominate the conversation. Therefore, sometimes it's important for the teacher to scaffold discussions to ease students' comfortability with speaking, and making sure that everyone gets a voice. In fact, "recurrent experiences of participating and being positioned in particular ways contribute to identity development," (Turner et al, 2013). If teachers can provide clear feedback that validates ELs' reasoning, as well as inviting them to share, justify, or clarify their thinking process that demonstrates them as competent problem solvers, then ELs gain confidence. Teachers should also invite other students to respond in such a way that positions ideas as important or as mathematically sound before moving on to the next idea (Turner et al, 2013). This allows more space for all students, rather than only the ones who start off being comfortable leading discussion or explaining a mathematical concept. Not only do student-led discussions have a positive correlation with improving performance, but continued positive experiences can lead to EL's enduring identity development with that subject.

Limitations of Review and Suggestions for Further Research

I chose this topic for literature review because I felt there was a lack of material in my education classes for supporting students who are learning English specifically in STEM classroom contexts. My coursework at Swarthmore College, especially EDUC 14: Intro to Education, EDUC 53: Educating Emergent Bilinguals, and EDUC 56: TESOL Methods and Practice encouraged me to think about issues of linguistic inequalities, and I became very interested with the idea of academic language and questioned its gatekeeping effects in learning new content. The often overlooked linguistic load of scientific and mathematical language is a major barrier to showing effective mastery of content, especially for ELs or those who aren't used to using standard academic English. I also was inspired by my coursework at Eastern University where I wrote a high school chemistry exam designed for English learners that also tested their language proficiency through their skills of reading, writing, speaking, listening, grammar and vocabulary. My fieldwork experiences at two charter schools in Philadelphia, one with a high population of Spanish-speaking and multilingual students, the other with a high population of black students using AAVE (African-American Vernacular English) additionally informed my review. Since I want to be an effective and equitable chemistry teacher in the future, I wanted to center my thesis around students that I had worked with before and likely would continue working with.

My literature review started by searching the Tripod Library database with the key words, "english learners" "secondary school" and "STEM" to find specific instructional practices and assessment modifications. I recorded the subject, age group, language and culture of the students studied (if applicable), and the main skills and practices addressed in each paper I thought most relevant. Then, I decided to split up instructional practices based on whether they were focused on addressing effectiveness or equity. There is definitely crossover between the two, as some articles addressed aspects of both. But I wanted to center the idea that both need to work hand-in-hand to deliver the best education possible to English learners. ELs' linguistic and cultural backgrounds need to be respected and nurtured throughout

the learning process to promote positive identity formations in STEM classrooms, but they also need to be exposed to the dominant linguistic modes, so that they can best be prepared for future careers or higher education. I wanted to capture practical instructional strategies that could be employed by STEM teachers to promote both of these goals.

It's important to note that most of the literature and research I found about supporting ELs in STEM learning centered on the elementary school level and junior high level (K-8th grade). This was especially true for the skill-based instructional strategies designed to help students more effectively meet standards. There was more secondary STEM education research for the equity-based instructional practices, but this trend was still generally true. This points to the need for further research in specific STEM content classrooms at the high school level. While there is wisdom and valuable insight from the elementary-based studies that can be applied to secondary STEM classrooms, secondary EL students are older, more mature, and are at a different life stage in preparing for adulthood. This is especially true for teenage newcomers. They have already had a chance to develop their adolescent identities in their home country, which makes the transition to United States culture much more difficult. They therefore have different needs and have more responsibilities that may be pulling them in many different directions, preventing them from being able to have as much focus on school as elementary students could give (Allard, 2015). There is a delicate balance between providing the appropriate support for English learners with low proficiency versus treating them as if they were children and potentially using strategies that would make them feel inferior. This means that some instructional strategies in this literature review may be less effective for older ELs.

While I was impressed at the number of studies that specifically tied together STEM learning, and English learners, I was surprised that the majority of studies focused on mathematics research. This is not a bad thing, and many of the math instructional strategies used with ELs can be applied in different contexts. However, this also suggests the need for more studies that are centered on lab sciences such as

chemistry, biology and physics. Other areas of research that should be explored in conjunction with best instructional practices for secondary STEM teachers working with ELs include the transition to life after high school. Whether students want to attend collegiate institutions or not, they should learn other skills that will prepare them for life beyond the high school classroom. This includes learning skills for presenting scientific information to different audiences in both spoken and written form. Learning how to write for research journals and delivering efficient and comprehensive presentations are difficult skills for fluent English speakers. English learners must be supported throughout these processes so that they can effectively communicate ideas from fellow members of the scientific community and a non-scientific audience when prompted.

Conclusions and Final Discussion

As was discussed, lessons and exams in the STEM classroom default to requiring standard English academic language in addition to regular content knowledge. This devalues the linguistic repertoires of speakers of other languages, including English learners (ELs) and speakers of non-standard English. Assessment of knowledge is also often measured through the mastery or completion of state and national standards. Because of this, many high school STEM classrooms focus on preparing students for standardized testing, which prioritizes academic language and procedural knowledge, rather than allowing students to learn material through linguistically and culturally diverse ways. Thus, there is a real need to make sure EL's needs and the supports provided align. So... what characterizes equitable and effective assessment and instructional practices for EL students in the secondary STEM classroom?

Over the last thirty years, there has slowly been a shift in how academics talk about instructional practices designed to help English learners. Many studies before the 1990s focused on remedial practices that valued high English proficiency over a students' rich linguistic and cultural backgrounds. Over time, more studies began to position diverse linguistic repertoires as assets, rather than deficits that must be overcome in order to perform well academically. And rather than just focusing on performance based

measures, such as evaluating test scores and students' ability to reach standards, more studies have begun to discuss the importance of identity formation in STEM classrooms as vital to continuing with the subject in the future. Proponents of performance-based interventions and identity formation interventions sometimes seem to work against each other. The former prioritizes accomplishment and mastery of STEM content, even if it means relying on standardized and status quo methods, while the latter prioritizes new and innovative methods for learning STEM that incorporate linguistic and cultural diversity that some argue detracts from the ability to address all content standards.

I argue that there should be an equal focus on effective *and* equitable STEM teaching. By addressing skill-based needs in the classroom, teachers make sure that students are prepared as best as possible to meet content standards. I highlighted the benefits, tensions and practical applications of instructional methods including visual aids, sentence stems, and explicitly teaching vocabulary words. By addressing the social need to feel like one belongs in a particular STEM field, content teachers are making their classroom environments more equitable. Some suggested instructional strategies they can follow include: normalizing translanguaging and translation, incorporating culturally relevant, responsive and sustaining pedagogies, and encouraging inquiry based student-led discussions. It is important to consider when and how these methods get used, and for the teacher to be aware of the theoretical framework behind the practices they choose to use. It is also imperative to present instructional modifications as having pedagogical value for all students, rather than just being remedial measures only for ELs. All students can benefit from these instructional and assessment modifications. This includes students for whom English is not their first language, those who must code switch between modes of English, or for speakers of standard language. Introducing more methods for learning content expands the likelihood of students mastering standards more quickly, and expands their perspectives on what knowledge should be valued in the learning process.

How can students like Natali and Kareem be supported in their individual goals during their time in the secondary STEM classroom? Natali is officially labeled as an English learner and Kareem is not, yet they both have wide linguistic repertoires that if utilized, could help them achieve academic success and maintain interest in the subject. Because Natali is categorized at a beginning English proficiency level, it may be hard for her to convey all of her previous content knowledge in her STEM classes. Therefore, it would be especially helpful to incorporate more scaffolding into her assignments and assessments. Visuals, sentence stems and vocabulary could be utilized to help Natali overcome the linguistic barrier, so that she can more easily participate in class and have a starting point to employ her previous knowledge. The amount of scaffolding should decrease over time after Natali has had the chance to become more comfortable with the content in both languages. Since her goal involves higher education, she needs to be slowly equipped with tools of academic English to best support her on that journey. In Kareem's case, it's more important that his linguistic and cultural background and skills are seen as valuable in the classroom. Since he has deemed himself no longer a "science" person, it may be hard to gain back his interest. If he can see that he is still valued in the learning process, he might be more willing to give his best work. To do this, his teachers should encourage translanguaging practices, seek out his community's values and needs, and center his voice in casual student conversations to help generate curious questions. These sets of instructional practices and frameworks are not exclusive to either of these students - they both can benefit from the practices suggested for the other. But based on students' self-stated goals, it may be better for teachers to lean into either skill-based needs or social needs. Both are important to consider and to implement, but some students may need one more than the other.

Notes

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