A Teacher's Guide To Introducing a Critically-Engaging Data Science Project

Intro

This guide offers a transformative approach to K12 computer science(CS) education. By combining culturally-responsive teaching with computational thinking frameworks, educators can create a dynamic and enriching learning environment. Within this guide, we delve into the significance of culturally-responsive pedagogy, explore three computational thinking approaches(cognitive, situated, and critical), and review their integration in a critically-engaging end-of-unit data science project. To start off, picture your first encounter with computer science, a moment that likely sparked your curiosity and desire to explore the world of technology.

My first experience began my senior year of high school, where I took an introductory computer science course and learned about iteration, binaries, and functions! I loved every bit of it, and couldn't wait to make cool new gadgets or develop cutting-edge technologies. After my first college CS course, I realized that there were only a few people who looked like me. This summer has been a fruitful one, and working with Dr. Proctor on this unit as an African-American female undergraduate CS student has encouraged me to think deeper about the direction of CS education in the United States, and how my past lived experiences pursuing this field has helped shape my identity and inform this guide. Most times, I am one of few Black people in the room(sometimes, the only Black person and/or only girl) and have often had doubts identifying as a computer scientist due to the struggle for feeling included in the community, as well as encountering microaggressions all four years. There is a major lack of diversity in CS, a white male dominated field with strong barriers of participation to other groups.(D'Ignazio, 2020) When we say 'diversity' most people would assume you need more ethnicities/cultures, but what we *really* mean is diversity in thought and of various lived experiences. We need all voices to have an equal chance of being heard. Looking back, I am grateful that I had the opportunity to take an introductory CS course in high school, as it sparked my interest, and gave me the passion and drive to pursue CS as a career. However, if we want to increase the diversity in the CS field, one solution is to examine the education level to support the next generation of computer science educators to educate the next generation of diverse computer scientists.

Culturally-Responsive Teaching

Here we introduce **culturally-responsive teaching(CRT)**, a pedagogical strategy aimed to culturally and linguistically engage diverse youth. (Scott, 2014) This practice requires teachers to be *connected* to their students in non-traditional ways. **Culturally-relevant pedagogy** must meet three criteria: an ability to develop students academically, a willingness to nurture and support cultural competence, and the development of a sociopolitical or critical consciousness. (Ladson-Billings, 1994) *But why should this be implemented in schools?*

Going back to personal experiences, I believe one of the reasons that I kept pushing through my CS degree despite the odds was my passion for learning about the world around me. Even as a child, I was naturally curious and academically talented. In elementary school, I remember being ecstatic when I was invited to join the school's gifted and talented program, for academically gifted students. I was the only Black girl, and I remember feeling ostracized by the other Black kids in the school for some reason. Ladson-Billings describes a study where, among Black high school students who were gifted in elementary school, only about half were continuing to do well academically. A closer look showed that the successful high school students' progress indicated they were social isolates, with neither Black nor White friends. I can say that this experience was true

for me in high school, as well, not ‘Black’ enough, and obviously not ‘White’ enough to fit in with either crowd. We can see this is true amongst other Black students as well. “Among the scholarship that has examined academically successful African-American students— their success came at the expense of their cultural and psychosocial well-being.” (Ladson-Billings, 1994) Now, there lies the dilemma for Black students - to maintain their cultural integrity while succeeding academically while navigating a field that has been historically exclusive to White males. This leads to a bigger question: *What kind of person do you need to be, or will you become, through participation in computer science?* This is just one example of why culturally-responsive pedagogy is so important, because you as the educator will help students in answering that question.

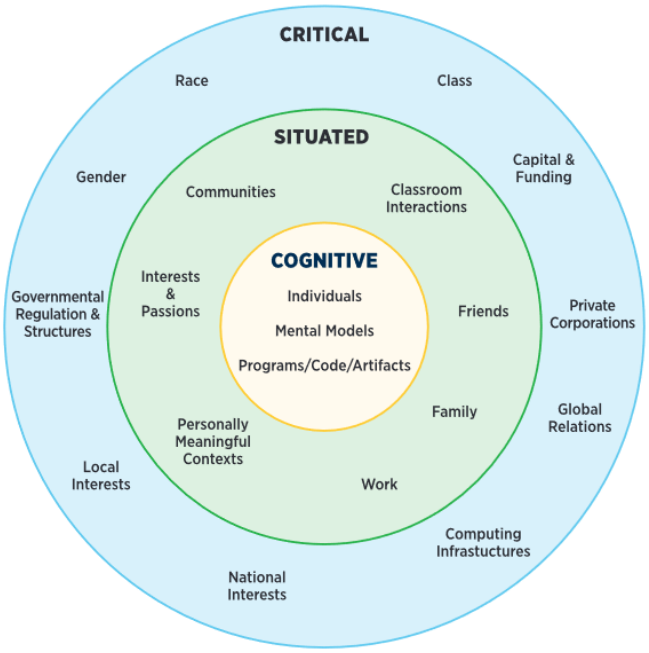
Computational thinking frameworks: cognitive, situated, and critical

Let’s jump back and recall your first introduction to CS. You’ll find that these concepts and skills that you learn are a part of **cognitive** thinking, one of Kafai, Proctor, and Lui’s (2019) frameworks of computational thinking with the aim to build skills and provide students with an understanding of key computational concepts, practices, and perspectives. Computational thinking can be described as the processes needed to engage with computational tools in order to solve problems. (Wing, 2006) In our data science project, we will be utilizing this framework through the use of Pandas and Jupyter Notebook. This is a main component of the project, but emphasis should be placed on the other two frameworks, **situated** and **critical**. The following paragraphs define **situated** and **critical** thinking, and what we plan to incorporate and introduce in this pivotal data science project.

The **situated** framing of computational thinking aims to emphasize personal meaning and creative expression, as well as connecting with others. This framing appears in the classroom as students working together in groups, students asking each other for help first, and a brief class presentation at the end of the project. This also appears in the initial planning phase, where students have the opportunity to connect their personal interests to the project. Free expression and inclusivity should be embraced in academic settings, where both teachers and students require inclusive freedom in order to inquire, probe, and question, establish views and new visions without fear of discredibility, punishment, or silencing(this is referred to as **epistemic injustice**, discussed in next paragraph).

Lastly, **critical** computational thinking is seen as a space to examine or engage with the political, moral, and ethical challenges of the world(i.e, surveillance state, food insecurity, climate change, etc.) This framing appears in all stages of the project. In the initial planning stage, students are asked to critically think about the world around them, and will create research questions that effectively address their curiosity. Example activities include:

- An afterschool project where youth interviewed residents and worked with designed to visualize gentrification in their neighborhood



- A group of students who are passionate about climate change review their county's overall energy consumption(water, gas, electric) and work together to visualize the data

In the reflection stage, students are asked to examine the social and ethical impact of the answers to their research questions, and reflect on the skills learned in this project and how it could contribute to society. The reflection stage is a pivotal point in this project, one where students are directly asked to think critically. This may be the first time many students have thought critically about their education and how what they learn can be applied beyond the classroom. Encourage students that there is no 'right' or 'correct' reflection. This reflection will be more meaningful if the student has chosen a research question/topic that is personally meaningful to them. At the end of the project and unit, students will give a brief overview of their project, so make sure to ask critically-engaging questions about the student's process and findings. Students are also encouraged to ask questions, but the teacher should make sure to ask at least one critically-engaging question for each student's project. A chart summarizing the class objectives for this project can be seen in the figure below.

Research(Cognitive/Critical)	**Reflection(Critical)**	**Brief Presentation(Situated)**
LO: Students will understand the importance of, and how to come up with an effective research question. **LO:** Students will be able to examine the priorities of their objective in relation to their chosen dataset. **How?** Students will come up with at least 5 research questions; students will get it approved through the teacher.	**LO:** Students will examine/analyze the social and ethical impacts between their objective and the dataset. **LO:** Students will reflect on the skills and information they learned in this project, and how it could contribute to society. **How?** Students will reflect on: - How they felt about their objective (What personal meaning did it have to them?) - The questions they chose to ask and the answers they hoped to get - The answers they got and future directions for them	**Classroom LO:** Students will give a brief overview of their project, their objective, their research questions, the process to find it, and one thing they liked about the project, and one thing they disliked. This should take <5 min per student. **How?** Teacher observes classroom is 'alive' and their identity shows up in presentation. Connected interdisciplinary interests; Create a classroom that is open to accept all identities.

Epistemic Injustice

When implementing these frameworks in the classroom, it's also important to avoid **epistemic injustices.** **Epistemic injustice** refers to forms of unfair treatment that relate to issues of knowledge, understanding, and participation in communicative practices, which includes silences, speakers/listeners' social status, marginalization, discrimination, etc (Walker, 2019). There are two forms of epistemic injustice: **hermeneutical** and **testimonial**. **Hermeneutical** is structural, evident when making an unjust/unfair experience understood by yourself to someone else. This type of injustice is understood by the powerless, but still not communicable to

those with power(teachers, schools, education system). An example can include a teacher being unwilling to listen to a students' contributions due to their immigrant status. This unequal participation of generating knowledge results in hermeneutic marginalization of people and/or groups. Be careful to avoid hermeneutical injustice appearing in your classroom by listening (and encouraging students to listen as well) to all students' contributions. **Testimonial** injustice refers to when the speaker has little to no credibility due to the listener's prejudices. If you notice yourself dismissing/overlooking a student when they try to participate in class, ask yourself what *unconscious* biases you have that led you to that decision, then make a *conscious* change for the better. Education is a space where **epistemic justice** matters, and it's important for students to be able to contribute to the shared resource of ideas, as it's fundamental to human well-being. (Fricker, 2015; Walker, 2019) The consequences of not consciously implementing epistemic justice into educational systems and practices are more damaging for future generations.

Data science is an ideal platform to introduce these concepts because it allows students to create an internal monologue to examine the power of their computing skills and the social/ethical impacts of it. For this project, we want students to not only know what data science is or how to answer statistical questions, but also realize the importance of data and ask questions such as: *Who has access to data? Who determines who has access to data? Who manipulates this data? Who draws the conclusions and makes claims from this data? What are the impacts of these drawn conclusions?* While drawing these conclusions, it also forces us to reflect on our place in the world and how our various lived experiences shape and affect our reality in society. We know that CS is a discipline where the technology is profoundly consequential on humans, and technological advances are, evidently, intertwined with ethical, societal, and political issues. These beliefs resonate deeply with Vakil's framework, which argues for a radical rethinking of humanizing technologies through a justice-centered lens. He takes a powerful stance on the future of CS education, *"Yet, if the field of CS education is to realize its potential as a force for justice in schools and society, a deeper and more critical engagement with the meanings and purposes of equity, beyond notions on inclusion and representation, is imperative."* (Vakil, 2019) Vakil's main points focus on the role of ethics in the curriculum, role of identity in CS learning environments, and the significance of a clear political vision for CS education. In parallel, these align nicely with our aspiration of approaching computational problems in a way that will allow students to engage with their cultural and political identities.

Conclusion

To conclude, the journey towards integrating critically-engaging data science projects into K12 computer science education underscores the transformative potential of these projects in shaping the perspectives and identities of students. The adoption of culturally-relevant pedagogy offers a vital approach to engaging diverse youth, fostering academic growth, cultural competence, and critical consciousness. The personal experiences shared in this guide highlight the significance of inclusivity and personal connection in shaping students' learning paths. Computational thinking frameworks - cognitive, situated, and critical - provide a structured foundation for these projects, allowing students to explore, collaborate, and critically reflect on real-world challenges. As educators, embracing epistemic justice becomes pivotal to ensuring equitable participation and fostering a safe, open environment for diverse voices. Introducing data science within this context serves not only as a means of developing technical skills but also as a powerful tool to question, analyze, and understand the ethical and societal implications of technology. The forward-thinking vision of integrating justice, ethics, and identity into CS education, as advocated by scholars like Vakil and Ladson-Billings, resonates with the overarching goal of preparing students to be conscious contributors to a technologically advancing world. Through the lens of this guide, it becomes evident that the fusion of data science, culturally-responsive

teaching, and critical computational thinking empowers students to explore their potential, ask meaningful questions, and ultimately shape a more inclusive and socially-aware digital landscape.

In this next section, here is a list of questions or concerns that teachers may have when implementing this pedagogical framework in their classrooms.

Q/A

What if some students aren't interested in the **situated**/**critical** aspect of the curriculum?

- ★ Although it's every teacher's goal to have every student engaged and excited about the curriculum, it's important to think back on these students' past experiences with grades. Students whose only concern is the grade are under immense pressure and stress to achieve high marks, often due to negative past experiences when they did not. It is disheartening, but understandable that these students will be set in their ways even after one, two, or a few talks about how the grade isn't meant to be an emphasis here. You can build a culture of trust, support, and affirmation for creative expression with disregard for grades, but you may not be able to change their mind with this project. However, this can be the beginning of a slow process of participating creatively in a learning environment and not be reprimanded for their creativity! [think about students who are interesting as well]

What if students have trouble creating a research question? - introduce generative themes

- ★ Using Freire's concept of generative themes, or themes that are educational, political, or social topics important to the people whom they affect. These are important because if you find that your students are having trouble thinking about the questions they'd like to ask, one solution would be to think about what affects them, whether they realize it or not.. A class discussion could be helpful in thinking of a general direction for this project, or even encouraging students to discuss within their groups. For example, I am writing this in the summer of 2023, and some sample topics could include natural disasters (i.e., What is the average number of acres burned per day during the Canada wildfires? Is there a correlation between food deserts and locations that never recover after natural disasters? Is there a correlation between GDP and the number of people who survive in a natural disaster?)

How do we determine if a student's research questions are 'unethical' if we may be unaware of it ourselves?

- ★

How do we educate a student who wants to ask an 'unethical' question?

- ★ Assuming the student has genuine curiosity and good intent, this is a great opportunity to introduce students to exploring how these choices may have negative impacts/consequences. Ask the student what led them to that question, and identify if it's rooted in any unconscious biases.

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