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Cultural competence or deficit-based view? A qualitative approach to understanding middle school students' experience with culturally framed engineering

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Abstract

Background: Recent policies have given momentum to the science, technology, engineering, and mathematics (STEM) education in the USA and throughout the world. This has resulted in rapid growth in engineering and STEM curricula, many of which incorporate global contexts to frame student experiences; however, little research has been done on the effects of this contextualization. Thus, it is critical to explore the impact of these curricula on student learning and the development of STEM identities, especially those who have historically been marginalized in STEM fields. The purposes of this study are to critically examine how STEM curriculum helps shape students' perceptions of the underlying cultural context and suggest ways that anti-oppressive education theory can be applied in middle school physical science classrooms. This study draws on classroom observational data and the curriculum text itself to understand how students perceive culture that they do not identify with.

Results: We found that the curriculum provides very limited perspectives of the non-dominant culture in which the learning was situated. Our results also indicate three emerging themes showing students to be demonstrating an elitist viewpoint, having a narrow view of another culture, or being indifferent toward the embedded cultural context in the lessons. As a class, deficit-based views of the people and places presented in the lesson were created rather than the desired culturally competent views. These negative perceptions were imprinted and solidified through limited portrayal of the embedded culture in the curriculum.

Conclusions: This work highlights the importance of curriculum context in students' learning. Beliefs about the people and places are created through global context presented in the curriculum. Portrayal of these people and places was not representative of the culture; thus, resulting in limited perceptions of the situated contexts. It is crucial that the teachers critically evaluate the curriculum prior to its implementation to make sure *Others* are represented appropriately by drawing upon the anti-oppressive education theory. Lastly, we also advocate for the incorporation of global culture in STEM curriculum by having students learn beyond what the written curriculum offers.

Keywords: STEM education, Anti-oppressive education, Physical science, Engineering, Middle school

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Background

Recent policies have given momentum to the science, technology, engineering, and mathematics (STEM) education in the USA, as well as many other countries throughout the world. Support for STEM education has come from both private and government sectors with many of them advocating for and painting the image of STEM being product- or thing-oriented (Bairaktarova & Pilotte, 2020). For instance, the *Rising Above the Gathering Storm* (National Academy of Sciences, 2007) highlighted the importance of STEM education programs as the key mechanism to get more students interested in STEM-related careers. Additionally, STEM education is also supported by the government through the president's recent commitment to fund K-12 STEM education (STEM and Computer Science, Preparing the 21st Century Workforce, 2017). Arguments for improving STEM education and creating a stronger STEM workforce to maintain global status in the USA date back to the Sputnik crisis in 1957 (Gardner, 1983). Similar argument from corporations, preparing qualified candidates to fill in STEM-related jobs such as "software developers, petroleum engineers, data scientists, and those in skilled trades" (Xue & Larson, 2015, p. 12), drive current STEM reform initiatives. Thus, STEM education is an important topic for educational practitioners, policymakers, and researchers, especially in K-12 settings where students' STEM identities are being developed toward consideration for future STEM pathways (Archer et al., 2012; Aschbacher, Ing, & Tsai, 2014).

The *Next Generation Science Standards* (NGSS) (NGSS Lead States, 2013) and the associated *Framework for K-12 Science Education* (National Research Council [NRC], 2012) document provide guidance on the implementation of STEM education reforms in the United States. A significant change is the integration of engineering and engineering practices through the addition of the Science and Engineering Practices. Researchers argue that engineering provides a meaningful and relevant context for learning in the STEM disciplines (Roehrig, Moore, Wang, & Park, 2012). As a result, there has been a rise in the number of engineering curricula and other STEM educational products (Leinfelder, 2018).

Given this rapid growth in engineering and integrated STEM curricula, it is critical that research explores the impact of these curricula on student learning and the development of STEM identities, especially those who have historically been marginalized in STEM fields. Although "STEM education is closely linked with our nation's social and economic prosperity" (STEM and Computer Science, Preparing the 21st Century Workforce, 2017, p. 2), the STEM fields are still dominated by white men subscribing to the masculinized cultures (Baird, 2018). Nationally, women make up only 19% of all undergraduates who enroll in engineering programs and Black, Hispanic, and Native American students make up only 16% of the enrolled students (National Science Foundation, Division of Science Resources Statistics, 2014). According to the national employment data, women make up 15% of the engineering workforce and Black, Hispanic, and Native Americans make up only 11% of the engineering workforce (National Science Foundation, Division of Science Resources Statistics, 2014). More voices from these aforementioned groups are needed in engineering to make engineering more inclusive toward traditionally underrepresented groups. Not only will this provide different perspectives to look at the engineering problems, but they will also likely lead to diverse ways to solve the problems.

One of the predictors of students' future career decisions, whether they pursue STEM-related disciplines or not, is their *science identity*. According to Gee (1999), *identity* is defined as "the kind of person one is seeking to be and enact in the here and now" (p. 13). Together with self-efficacy and a sense of belonging, Trujillo and Tanner (2014) placed great importance on science identity and characterized science identity into three dimensions: recognition, competence, and performance. Hazari, Sonnert, Sadler, and Shanahan (2010) added *interest* as the fourth dimension of science identity. These four dimensions are very relevant to underrepresented minorities. For instance, women of color in the STEM field persist in science "by redefining their understanding of what it means to be in science and whose recognition is important to them" (Carlone & Johnson, 2007, p. 1210). This also shows how important it is for traditionally marginalized students to develop their science identity early on so they can be successful in the STEM fields. One important consideration is how these new STEM and engineering curricula represent people within STEM.

STEM identities are known to develop early in a student's education, making elementary and middle school critical years for STEM identity development (Archer et al., 2010; Catsambis, 1995; Sadler, Sonnert, Hazari, & Tai, 2012; Tai, Liu, Maltese, & Fan, 2006). Exposing children to STEM disciplines at an early age is beneficial to children's learning, and it is crucial that the lessons "be specifically tailored to the gender and ethnicity of the students being taught" (Catsambis, 1995, p. 253). Two potential ways that curriculum developers attend to students' interest and identity are to ground engineering problems in real-world contexts (Moore et al., 2014) and to use a coherent narrative (Martin & Brouwer, 1991) to engage students in learning content. Many STEM curricula, such as the Engineering is Elementary (EiE), use global contexts as the real-world setting for students to engage in engineering design tasks. However, the use of

contexts not centralized on the communities or lived experiences of the students can be problematic (Gruenewald, 2003). Especially with globally contextualized lessons, the effect of misrepresenting global information has not been explored. Given how harmful and oppressive subconscious learning or hidden curriculum can be (Portelli, 1993), researchers suggest ways to overcome this oppression that can occur through curriculum representation (Bates, 2005; Iseke-Barnes, 2005). Thus, this qualitative study investigates an engineering unit in which students are engaged in the design challenge addressing the needs of a hypothetical client and end-users from Ecuador. Specifically, our study's overarching question was concerned with how engaging in a STEM unit with a cultural context impacts students' cultural attitudes and understanding of STEM. The research questions that guide this study are the following:

RQ1: How does the curriculum text influence students' cultural perception of non-dominant country?

RQ2: What did students report learning about the people represented in the curriculum who live in the Ecuadorian province of Esmeralda, the city the unit takes place in?"

Literature review

Incorporation of engineering in K-12 curriculum and standards

Within the USA, the NGSS (NGSS Lead States, 2013) are the suggested standards through which STEM education should be reformed. While not all states have adopted the NGSS, nearly two-thirds of US students experience education standards influenced by the NGSS, with 19 states and the District of Columbia adopting NGSS and 21 other states developing their own standards based on the NGSS (National Science Teacher Association, 2014). The NGSS standards mark the first explicit inclusion of engineering at the federal level. To highlight the importance of engineering in science practices, the NGSS authors state:

> We anticipate that the insights gained and interests provoked from studying and engaging in the practices of science and engineering during their K-12 schooling should help students see how science and engineering are instrumental in addressing major challenges that confront society today, such as generating sufficient energy, preventing and treating diseases, maintaining supplies of clean water and food, and solving the problems of global environmental change. (NRC, 2012, p. 9)

Additionally, instead of confining engineering to a select group of professionals, the integration of engineering into the NGSS intends for students to understand that the problem-solving practices grounded in engineering are for all citizens.

The NGSS Framework highlights the importance of socially relevant contexts in science lessons (NRC, 2012). Engineering provides learning contexts situated in real-world problems for students to learn science and mathematics (Brophy, Klein, Portsmore, & Rogers, 2008; Roehrig et al., 2012). According to the *Framework for Quality K-12 Engineering Education* (Moore et al., 2014), an important element of engineering curricula encompasses both local and global knowledge of the problems and solutions. This contextualization of learning is used to both engage students and situate the content of the curriculum.

Gaps in literature

In response to these calls for the integration of engineering into science classrooms, the development of K-12 engineering curricula to meet the needs of school districts and states has grown exponentially. As mentioned in Chabalengula and Mumba (2017), some examples of curriculum developed in response to the NGSS are the following: Engineering by Design; Engineering is Elementary; Infinity Project; Project Lead the Way; City Technology; Learning by Design; Gateway to Technology; Engineering by Design; Engineering for Today's Intermediate School; World In Motion; Teach Engineering; and Principles of Engineering (p. 2210).

These curricula with engineering design context are currently being implemented throughout the USA and have been shown to have many benefits. For instance, Project Lead the Way increases students' reading, math, and science scores (Bottoms & Uhn, 2007). Another curriculum, like the EiE, encourages historically underrepresented students in STEM to take up more leadership roles and attracts them to science and engineering (Moffett, Weis, & Banilower, 2011) through contextualized narratives (Koul & Dana, 1997; Martin & Brouwer, 1991). However, little emphasis is placed, with respect to research, on the cultural aspects of STEM curricula. Chung (2011) briefly mentioned the importance of cultural competency skills for all engineering graduates in our diverse society; yet ways to develop these skills were not described and left for instructors to figure out on their own.

Unfortunately, the high demand for engineering curricula may have placed greater importance on developing units for immediate implementation before conducting research on cultural appropriation within the unit. Cunningham and Lachapelle (2007) have shown that students generally perform better at school in the STEM-related subjects when they learn science through the EiE curricula as compared to their students in non-EiE curricular spaces. Their rationale for using diverse groups of people (e.g., people with disability and people

from rural villages in Asia) as context behind learning was to show students that anyone can become an engineer (Cunningham & Lachapelle, 2016). Many teachers, as cited in Moffett et al. (2011), see EiE as providing opportunities for all students to succeed, "noting that the activities are hands-on, are scaffolded, and allow teachers to differentiate to meet the needs of all of their students" (p. 9). However, research has not been conducted on how such curricula represent (or misrepresent) people and culture from other countries.

Problem scoping is generally the first place where students learn about the clients and the problems (Watkins, Spencer, & Hammer, 2014; Wilson-Lopez & Minichiello, 2017) regardless of what cultural messages the unit is sending. Since problem scoping is an important part of engineering design, it is important to understand the context of the problems such as criteria and constraints prior to designing and building solutions. Additionally, recent research (Kouprie & Visser, 2009; Walther, Miller, & Sochacka, 2017) considers empathy as equally important to criteria and constraints. Some engineering design processes are person-oriented (Bairaktarova & Pilotte, 2020) and start with "Empathize" stage (Dam & Siang, 2017). Through empathetic design, both the researchers and designers are focusing on the end-users by "trying to get closer to their lives and work,… empathise with them, with their experience and emotions" (Steen, Kuijt-Evers, & Klok, 2007, p. 10) as well as seeing design as "a way to genuinely engage with and involve users (and other stakeholders) in the development of solutions that best fit their needs and life circumstances, rather than simply the economic bottom line of designers" (Walther et al., 2017, p. 132). Empathy means to identify with and not to pity someone. It has become a norm in our society for people to show pity and help those who are less fortunate (Mead, 1985), which often consists of traditionally marginalized groups and those from developing countries. However, the unintended cultural representations may also further marginalize under-represented students and negatively impact their learning.

One particular example, where the focus of engineering design is on the well-being of humans whom the designs are for, is a human-centered design approach (Bairaktarova & Pilotte, 2020; Zoltowski, Oakes, & Cardella, 2012). Miller, Rosser, Benigno, and Zieseniss (2000) discovered that women are attracted to science, engineering, and mathematics that provide them with opportunities to help others. However, many students perceive engineering from a thing-oriented perspective where engineers create things and design solutions (Bairaktarova, Pilotte, Evangelou, & Cox, 2013). Thus, by changing the narrative of engineering and other STEM curricula from thing- to person-oriented, there could be more women being represented in STEM. Particularly, Bairaktarova and Pilotte (2020) highlighted the importance of reframing engineering curricular to also focus closely on "how truly authentic the engineering culture presents itself through the practices, values, and heroes presented to students in educational settings; through the faculty; and in the nature, content and dynamics of their coursework" (p. 9). Taking a step further, Mitcham and Muñoz (2010) advocated for a humanitarian engineering where the goal of the design is to meet "the basic needs of all—especially the powerless, poor, or otherwise marginalized" (p. 27). STEM should not be just thing-oriented; rather, it is about solving human problems in holistic ways while encouraging marginalized populations to participate in STEM. Thus, it is essential to look at STEM education from an anti-oppressive lens in order to see if curricula favor one group over others or if marginalized groups are further marginalized.

Researchers working toward anti-oppressive education argue that schools are spaces where the *Others*, those who are not a part of the dominant culture that is represented in school, are treated in harmful ways (Emdin, 2016; Kumashiro, 2000). Harm can come directly from what students and teachers say, but also indirectly from the curricula choices that are made. Walgenbach and Reher (2016) identified "social collectives including men, Whites, heterosexuals, and the educationally privileged etc. (p. 189)" as the recipients of societal privileges in the dominant Western cultures. These privileges are reflected in school curriculum across multiple disciplines in Western schools, and are also reflective and in favor of those from the dominant groups.

When curriculum is created for the privileged group, it becomes a source of oppression for the *Others* who are left out of that academic space (Kumashiro, 2002). Freire's (1982) educational banking system claims that students are taught to memorize and bank their instructed knowledge; thus, resulting in an oppressive society where critical consciousness, or the ability to think for oneself and question what is being told, is limited and discouraged. Although STEM curricula continue to include global and cultural contexts, not much research has been done on the effects of this contextualization. We generally perceive schools as places where dominant societal values, cultures, and norms are practiced and passed on to students. In a way, schools facilitate the construction and maintenance of social order (Claydon, Knight, & Rado, 1977), thus, solidifying the "disadvantage" or marginalized status. In response, recent trends in education have called for incorporating students' prior knowledge into the lessons to engage students and to make lessons more inclusive to the *Others* by making them relevant to the real-world contexts (Brown, Collins, & Duguid, 1989), "personally meaningful and easier to master" (Gay, 2013, p. 51). One

other alternative is to focus on the cultural resources that students bring to class through asset-based education (Expósito & Favela, 2003). Expósito and Favela (2003) also argue that teachers who critically engage in reflective practices and navigate through their teaching and learning roles are more likely to succeed in a classroom with diverse student populations. Unlike deficit-based approaches, asset-based approaches utilize the strength and opportunities that the community provides rather than the problems or needs of the community (Green & Haines, 2008).

Anti-oppressive education framework

Kumashiro (2000) describes four types of education where oppression can occur and how they can be overcome: *education for Other, education about Other, education that is critical of privileging and Othering*, and *education that changes students and society*. First, education for *Other,* requires instructors to recognize the differences among *Others* and provide students with safe, "helpful spaces" for everyone from both infrastructural and classroom environmental perspectives. Furthermore, instructors are also required to recognize schools as harmful spaces where oppression takes place. However, it is becoming more challenging for the teachers to do so in our current diverse society where students can easily adopt new persona or change their identities. This makes it even more difficult for us to define who the *Other* is.

In his second type of education, Kumashiro focuses on designing lessons and curriculum that educate about the *Other*. The goal should not be about filling the knowledge gap about the *Other* but rather to modify our biased knowledge of the *Other*. To do so, instructors are encouraged to incorporate curriculum that addresses basic knowledge about the *Other*. This can be done throughout the curriculum, which might encompass information about what most people do for a living or what their traditions are, etc. for students to have a better understanding of whom the curriculum is about before coming up with potential and appropriate solutions. Thus, students will have more opportunities to learn about other ways of being and develop more empathy toward *Otherness*. Moreover, they will also be able to demonstrate cultural competence toward the *Others*, which Ladson-Billings (1995) identified as an essential aspect of culturally relevant pedagogy. As a result, students can perceive other ways of living as normal, thus, bridging the *Otherness* gap.

The third recommendation Kumashiro gives is education that is critical of privileging and *Othering*. Through this framework, teachers are encouraged to teach their students about the oppression and ways to overcome it. Essentially, students develop as critical thinkers who always question and look beyond what is told or taught. Being more complex than the first two types of education, education that is critical of privileging and *Othering* requires instructors to question the notion of individual and societal privileges. Furthermore, having knowledge about oppression is not enough. Students should be taught critical thinking skills that empower them with tools to fight against oppression. Freire (1982) calls it *conscientization* or consciousness raising. Similarly, Ladson-Billings (1995) defines it as raising sociopolitical consciousness or having students be able to "recognize, understand, and critique current social inequities" (p. 476).

Lastly, the fourth type of education is education that changes students and society. In order to achieve this type of education, teachers need to instill the desire for change and differences in their students. Oppression, according to this type of education, can also come from the discourses themselves, especially through "ways of thinking that privilege certain identities and marginalize *others*" (Kumashiro, 2002, p. 50). To overcome oppression, unlearning what has already been learned about *Otherness* is necessary. This unlearning process is more likely to lead to a state of crisis where further learning may be resisted. Perhaps, as Kumashiro asserted, "we resist anti-oppressive practices because they trouble how we think and feel about not only the *Other* but also ourselves" (p. 57). Thus, overcoming our stereotypes of and resistance to knowledge about the *Others* are necessary for an anti-oppressive education. Given how diverse our classrooms have become, it is critical for instructors to steer away from oppressive lessons about already marginalized groups of people.

Methods

Context

This study took place in the context of a larger NSF-funded project. The goal of the project was to provide professional development for science teachers (grades 4-9) toward developing and implementing integrated STEM curricula in their classrooms. Each STEM curricular unit was written by teams of teachers during professional development sections, piloted in a summer school program, then revised and implemented during the academic year. The overarching goal of each unit was for students to learn science content through the incorporation of the engineering design process, following the *Framework for Quality K-12 Engineering Education* (Moore et al., 2014). This framework defines STEM as incorporating "some or all of the four disciplines of science, technology, engineering, and mathematics into one class, unit or lesson that is based on connections between the subjects and real-world problems" (p. 38).

Curricular context

The Ecuadorian fishermen unit was grounded in the *Quality K-12 Engineering Education Framework* (Moore et al., 2014) with a specific focus on learning heat transfer concepts and applying these concepts to develop design solutions. Sixth-grade students were introduced to the central problem through a client letter during the problem-scoping stage. This letter included the criteria and constraints for the requested design. In this unit, students were tasked with designing and building a small cooking device for the Ecuadorian fishermen to cook and sell their fish at the local fish markets. Specifically, the client asked students to design "a cheap container to hold and help cook the fresh fish in a solar oven while the fishermen are at the market." The project criteria and constraints asked that the cooker be small yet big enough to accommodate multiple fish at the same time, cheap enough so fishermen can make some profits, hot enough to cook fish, and safe enough for fishermen to leave the cooker unmonitored while they worked at the market. The fish cooker designs were then tested and modified before being presented to the client either in a written or presentation format. This unit utilized the context of a non-profit organization that helps rural villages in Ecuador. Table 1 provides an overview of the lessons in the Ecuadorian fishermen unit.

Participants

The participants in this study comprised 47 students and two veteran science teachers from two different middle school science classrooms. Class A comprised 19 students, five white students, and 14 students of color. Class B comprised 28 students, 22 white students, and six students of color. Mr. Patrick, the teacher from class A identifies himself as a white male. Ms. Natasha, the teacher from class B identifies herself as a white female. All teacher and student names are pseudonyms to protect their identity. Both classrooms were located in large public schools from an urban region of the midwestern USA.

Data collection

At the end of the unit, students in class A were asked to complete open-response survey questions to gage their perspective of other cultures after having helped their Ecuadorian client solve a problem. The prompt was as follows: How has this project, if at all, affected your perspective on other cultures? A variation of the same question was asked in class B on the last 2 days of their unit implementation to provide more focused information. Questions on the first day were as follows: Who is the client? How important is it that the client is from Ecuador? What problem is the client trying to solve? What are the criteria and constraints of the project? Questions on the following day were as follows: What is

Table 1 Lesson summary of the Ecuadorian fishermen unit

Lesson	Title	Content description
1	Defining the engineering problem	Students learn about the client and her needs, project criteria and constraints, central problems, and engineering design cycle.
2	Temperature and heat transfer and convection	Students learn about thermal energy, temperature, and heat transfer through convection.
3	Heat transfer through conduction	Students learn about heat transfer through conduction and hands-on experiment where they record the time it takes for an ice cube on different materials to melt.
4	Heat transfer through radiation	Students learn about heat transfer through radiation and hands-on experiment where they measure the temperature of air in a cup covered by different materials.
5	Analyzing the absorption property of materials	Students create temperature vs. time graph using the data they collected, interpret these data, and conclude about the materials' abilities to absorb, reflect, or transmit radiation.
6	Getting to know the context	The teacher introduces the agar model fish and the solar oven cooker to the students. These students then make observations and describe the design, justifying why the class solar oven has a black bottom and covered by aluminum foil throughout.
7	Exploring materials and planning: Idea generation	Students review the engineering design challenge and explore all the available materials for their final design. They also individually design their prototypes and write up the cost and materials used.
8	Planning: Idea selection and evidence-based reasoning	Students share their individual ideas with their teammates and select one idea for their group design. They also justify their reasons through evidences.
9	Trying/building the first prototype	Students construct their fish cooker based on their prototype design.
10	Testing and deciding about the first prototype	Students test their prototype, obtain data, and evaluate how well their design work.
11	Redesigning a second prototype	Students redesign to make their cooker better, construct the new cooker, and test it before deciding as a group which of their cookers will be suggested to the client.
12	Communicating with the client	Students present their cooker to the client through their choice of representations.

your perception of Ecuador (and/or other cultures)? Think about your past experiences with your family, friends, and teachers, what does this lesson remind you of? Before the questions were given out to students, both the researcher and the teacher made sure to address the whole group that there was no right or wrong answer and that we were simply interested in looking at what they were thinking. These questions provided an opportunity to explore students' perception of other cultures and thinking beyond what was written in the curriculum. They also helped us to understand students' opinions and experiences of a specific culture—and if culturally framed engineering lessons benefit student learning.

Observational field notes were used as a guide for any mention of the client and the problem students were tasked to solve. These notes provided cues for the researchers to select and to watch appropriate video recordings of the lessons that had discussions or mentions about the client and the unit central problem. Within these videos, selected discourses surrounding Ecuadorian fishermen and the fish cooker were transcribed and analyzed using Bloome's (2005) microethnographic discourse analysis approach to look at how teacher influences what students learn. Lastly, the curriculum unit was also used to answer our research question. We analyzed the entire curriculum: written and enacted—particularly looking at how Ecuadorian people are portrayed and represented.

Data analysis

For the first research question, critical document analysis was conducted on the curriculum to understand how historically marginalized people in STEM were represented. First, a search of the document was conducted to look for culturally related terms and traditionally marginalized groups of people in the entire curriculum. Given that the majority of these terms were found in the client letter, a critical analysis of the client letter was conducted. Furthermore, the two introductory videos about Ecuador in the curriculum were also critically analyzed. These videos were used by the teacher to introduce the engineering design challenge.

For the second research question, class A students' written responses to post-test questions were deductively coded (Corbin & Strauss, 2008). Specifically, student perceptions on Ecuador and Ecuadorian culture were looked at. Next, axial coding (Corbin & Strauss, 2008) was used to arrive at larger themes resulting from the deductive coding process that took place. One example of these themes includes deficit-based view, which has to do with the conceptualization of "the target individual or group primarily (or even solely) in terms of their perceived deficiencies, dysfunctions, problems, needs, and limitations" (Dinishak, 2016, the "Introduction" section, para. 1). Next, class B's responses were deductively coded using the emerging themes from class A to ensure that any supporting or opposing expressions in the findings were not missed. Furthermore, classroom conversations surrounding the Ecuadorian Fishermen context were selected, transcribed, and analyzed to see how the teacher and the students perceived this aforementioned context (see Additional file 2 for details of transcription notation). Since both the written and enacted curricula were considered, it was also important to listen to what the teacher said about the Ecuadorian fishermen context.

Results

R1: The curriculum provides very limited perspectives on Ecuadorian culture

There was a limited portrayal and description of the people and cultures of Ecuador in the written curriculum itself. Out of the entire unit, only the first lesson provided some background information on the fishing village where the Ecuadorian fishermen end-users reside. This information about Ecuador was taught through the client letter and two video clips: the first clip was on the Manta Ecuador fish market by the beach (ScriptSocket, 2012) and the latter clip was on the Galapagos Islands (Brogan, 2013).

The Galapagos Islands video showed several beautiful outdoor places around the Galapagos Islands that the filmmaker, a white Canadian woman made during her travel cruise experience. This, by itself, privileged who has access to the activities she experienced. The high cost of cruise was not something within reach of most of the urban families of the students and might have deterred the locals from participating in the same activities. The only sound from the film was from a background instrumental song called *Enjoy Your Life* by the Arkashic records. Most students were paying close attention to the video while it was being shown, which could partly be because of the colorful pictures and soothing background music.

The second clip, on the other hand, showed a more authentic view of Ecuadorian culture, but it was limited only to the fish market perspective. Unlike the first clip, students did not pay close attention to the video. Many of them were seen interacting with their neighbors or having their heads away from the projector screen. This was likely due to the loud unedited background of human and animal noises, as well as the unpleasant sight of dead sea animals for sale. Lack of interest could also stem from not understanding Spanish conversations in the film. Nonetheless, simply watching one short clip of the Ecuadorian fish market was not going to make students knowledgeable about or empathize with the

Ecuadorian culture. There were some disconnections between reality and what we think of as Ecuadorians' daily rituals; thus, students developed their perceptions of Ecuador around what they saw. These video clips contributed to two of the overall themes from the analysis—having a narrow view of other cultures and developing an elitist viewpoint.

While both clips showed certain aspects of Ecuador, they were rather limited. Many cultural and traditional contexts were left out, and only the perspectives shown in these clips were expressed by students and the teacher throughout the unit. These lessons taught about the *Others* albeit the biased knowledge conveyed to students. After the film, Mr. Patrick asked the class: "So, do you think they [Ecuadorian fishermen] make lots of money with what they are doing right now?" Students unanimously responded "NO, not really" placing an emphasis on the word "No" through elongating the vowel and saying it loudly. These students saw scenes of nature and the fish market, and they perceived all Ecuadorians from a deficit-based view as being poor.

The client letter also elicited this limited view of Ecuadorian culture. For instance, the Ecuadorian fishermen curriculum client letter states:

> We are contacting you in hopes that you will help us find a solution for a problem here in the Province of Esmeralda. … Our latest project is assisting fishermen in villages on the coast of Ecuador with proper cooking of fish while at the fish market. Fishermen travel several hundred miles to San Cristobal Island in the Galapagos to catch the best fish the area has to offer. Now those fishermen have come to us and said that they are interested in selling cooked fish at the fish market in addition to the raw fish they already sell, but they do not have a good way to cook them in the solar ovens that are available to them. They are in need of a small cooker container to hold each fish as it cooks in a solar oven. Since fishing is the number one occupation in the province of Esmeralda, it is important for us to assist them...This way, the fishermen can earn more money in the fish market, which will improve their quality of life and also help benefit their families and villages. (see Additional file 1)

The client letter assumes that the Ecuadorians are not capable of designing and building their own fish-cookers. It also paints an image of Ecuador as a fishing town that needs help from foreigners when in fact, fishing is not the main employment industry in Esmeralda (Ecuagringo, n.d.) and in Ecuador (InterNations GO!, 2019). Oil and agriculture are the two largest employment sectors of Ecuador with Esmeralda refinery being one of the three largest oil refineries in the country (Energy Information Administration, 2011).

Beyond the first lesson, students learned about the engineering practice and the science behind heat transfer without reference to the Ecuadorian culture. There was no further mention of the Ecuadorian fishermen, people, or culture at all in the written and enacted curriculum after the first lesson. The curriculum advanced a Western view of science, when students can learn more from embracing both Western and indigenous views of science since "our understanding of [modern] science is one knowledge system among many others" (Iaccarino, 2003, p. 223). With limited access and time for students to immerse themselves in understanding Ecuadorian cultures, misconceptions on the Ecuadorian culture were constructed and perceived as discussed in the following section.

R2: From the analysis, the following three themes emerged related to the second research question

Demonstrating an elitist viewpoint

Several students talked about the Ecuadorian people being less fortunate than themselves and how these people need help from others. For example, Marco wrote "I think that it's important to help people in need. So I think that if we give this [fish cooker] to the fisherman they really would have a better way of living life." Marco's comment shows the comparison that he is making between himself and the people of Ecuador—that the Ecuadorians did not have a cooking system comparable to the one Marco was accustomed to; thus, their lives were relatively not as *good* as Marco's. Furthermore, Marco's comment said a lot about his positionality with respect to the social hierarchy between him and his supposedly *Ecuadorian fishermen* from Esmeralda, Ecuador. Although Marco's opinion could be deemed as selfless, his usage of the word "really" implied and supported his elitist viewpoint that the Ecuadorian fishermen needed their help to build the fish cooker so they could lead a better life. To further support this claim, almost every student group in Mr. Patrick's class mentioned that Ecuadorian fishermen need our help in order to have a better way of life on their posters presented at the end of the unit.

While helping people in need can be an empathetic act, it also establishes a hierarchy in a social order where other cultures could be considered inferior to the Western culture. Marie stated "It [the Ecuadorian Fisherman unit] has opened my eyes to donating to other countries and places that don't have the good things like we do" and Tamya echoed this thought when saying "It [the Ecuadorian Fisherman unit] did because I know other people struggle and need help." From these statements, we conclude that both girls are positioning themselves

above the Ecuadorian people based on the perceived needs of the Ecuadorian people. Brian commented "it [fish cookers] would help people from different cultures to have better stuff like we have, an average amount of good stuff. And so it [fish cooker] could help them do stuff better." Here, the word "better" implied that people from the Ecuadorian culture lead a worse life than that of Brian because the quality of the Ecuadorian people's stuff is "lesser" and Brian's is "better." The unit seemed to create a hierarchy partially based on the quality of life, placing Westernized living at the top and making it ideally desirable. Estella's statement "so we said that they [Ecuadorian fishermen] needed a fisher cooker to have a better way of life. And the fish has to heat up and be cheap and reusable" is an example of a student who has fetishized the Western way of life because of the way the unit portrayed the client and their needs. The unit specifically tasked students to build a "cheap" solar oven. The students repeated this language in their responses. It was clear that the language used in the engineering challenge affected students' perceptions of Ecuadorian people. These statements illustrated the Ecuadorian fisherman's way of life to be inferior to those engaging in the engineering unit. Furthermore, it could also be interpreted that the Ecuadorian fisherman needed help from a more developed country in order to solve their problems.

The language in the written curriculum also supported this elitist viewpoint by highlighting how crucial it was for students to help design a desired fish cooker so the Ecuadorian fishermen can sell their cooked fish to make more money and improve their way of life. This was also illustrated through how Mr. Patrick addressed his students upon being asked about the main problem they were trying to solve (see Table 2). On another instance during the same day of unit implementation in lesson 12, Mr. Patrick mentioned a better way of life again when asked by one of his students, as seen in the conversation in Table 3.

In the same lesson, Mr. Patrick once again addressed two students about the client letter upon being asked what the main problem is (see Table 4). Both times, he recited the language expressed in the client letter about how Ecuadorian fishermen needed help from the student engineers to earn more money and have a better quality of life. As a result, his student, Lebron, registered and repeated exactly what Mr. Patrick said.

Having a narrow view of another culture

When the client letter was introduced, there was limited information about the Ecuadorian client. All it said about the client was the organization's name, its roles, and its latest project as seen below.

> As members of The Pescadores Foundation, our job is to help villages around the world by promoting and teaching new methods in harvesting, preparing, and marketing food. Our latest project is assisting fishermen in villages on the coast of Ecuador with proper cooking of fish while at the fish market (Additional file 1).

During the unit, students were repeatedly asked to reference the client letter to demonstrate their knowledge of the problem they were asked to solve. When looking over student responses, it seemed the client letter's language influenced how these students viewed the people and culture of Ecuador. For instance, Mark said "[Ecuador is] a tropical, non-advanced [place]" upon being asked for his opinion of Ecuador, which resonated with how both the written text and video being shown in the curriculum portray Ecuador and its people. Although the client letter described fishing as being the primary occupation for one selected town, students thought that fishing was the primary occupation for all of Ecuador. Mohamed wrote that "If they sell cooked fish over there they would make more money because more people wanna buy cooked fish." Mohamed believed that the Ecuadorian economy revolved around the fisherman selling cooked fish. His limited exposure to Ecuadorian economics made him believe that selling cooked fish would lead to more money without considering all the influencing factors and the possibility of alternative employers. In addition to believing that fishing was the only occupation, students also developed the belief that the main source of cooking in Ecuador was an open

Table 2 Conversation between Mr. Patrick and Ernesto during the last day of the unit in lesson 12

Speaker	Content	Observation/code
Mr. Patrick	Ernesto, can you tell me what the problem is we are solving?	Initiating
Ernesto	E::::r (1.2). We ne:::d to build like a (.) We need to build a fish cooker for the fishermen before they can have an easi[er]	Responding. Referred back to what he remembered the teacher was saying
Mr. Patrick	[an easier way of life? An easier life?	Evaluating
	Once again, if you go back to 8a in your Ecuadorian notebook, you should have that written out already. You can also double check that on your rubric to make sure that I give you all YESes on that so that it was correct.	

Table 3 Conversation between Mr. Patrick and Jacob during the last day of the unit in lesson 12

Speaker	Content	Observation/code
Jacob	Mr. Patrick, how should we describe why it's important?	
Mr. Patrick	Why do we want to build this for the fishermen?	Initiating
Jacob	So they can have a better way of life.	Responding Once again, student went back to the default mode s aying "better way of life"
Mr. Patrick	So the problem supports because the fishermen are poor and we want them to have a better (.) make more money so they can have a better way of life.	Evaluating
Jacob	Okay	

campfire. Samir reiterated what many other students wrote when asked about the life of Ecuadorian people, "it would've been homemade fish with a campfire." This statement implied that Samir perceived Ecuadorian people to cook fish at home through campfire, that their way of life is more primitive because they do not use gas or electric-powered stoves.

By the end of the unit, students showed very little knowledge of Ecuador beyond what was written in the client letter. Some students were uncertain where Ecuador was located. After supposedly learning about the country, its fish market, and the fishing industry, Yang responded to the end-of-unit student survey by describing Ecuador as "large crowded, large amounts of lakes and rivers. Oceans?" Despite the instructor showing clips of Ecuador's coastal area and describing its fish market, Yang was still uncertain if Ecuador was located next to an ocean. Other students like Alice perceived Ecuador to be "poor but beautiful and a lot of fishing." Chin viewed Ecuador as "hot dry and humid, hard to get food and water."

Being indifferent toward the embedded cultural context in the lessons

Students learned science regardless of the cultural context embedded in the unit. When Ms. Natasha asked the entire class on the last day of the unit "How important is it that the client is from Ecuador?" most students were indifferent toward who the client was. Some did not even care if the fishermen were Ecuadorians. Only one student, Martha, said it was great to have an authentic context behind learning so "it's a real truthful thing" (see Table 5).

Beyond the first lesson, Ms. Natasha did not discuss the Ecuadorian fishermen at all until lesson 12 where she asked her students the questions we provided. Even then, when Ms. Natasha talked about the client, she referred to them as either "fishermen" or "they" (see Table 6).

Discussion

The Ecuadorian fishermen curriculum does not accurately portray the Ecuadorian culture. The students' perceptions of Ecuador were shaped by the videos they saw, the client letter they read, and other information the teacher provided. Simply using another culture as a context for STEM curriculum without critically evaluating it from an anti-oppressive lens leads to unintended disrespect, stereotypes, and deficit-based perception of the culture. If the goal is to only teach STEM concepts, instructors should select curriculum with context that students can identify with in order to have meaningful learning. However, we are advocating for a global context to help students become global citizens. Aligning with Kumashiro's second tenet of anti-oppressive education: education about the *Others*, it is necessary for instructors to provide time for students to learn about and engage with the Ecuadorian culture throughout the whole unit.

There were several moments where Mr. Patrick discussed Ecuadorian fishermen in the lessons. This opened up conversation about the *Others* and is a great first step toward an anti-oppressive education. However, their conversations on the Ecuadorian fishermen were limited. They were mostly about the importance of helping the Ecuadorian fishermen improve their way of life. Students were so set on helping these fishermen whom they had not even met or learned about. Kumashiro would argue

Table 4 Conversation between Mr. Patrick, Lebron, and Dmitriv during the last day of the unit in lesson 12

Speaker	Content	Observation/code
Mr. Patrick	They are in need of a small cooker… [inaudible] so they can earn more money at the fish market so they can improve their quality of life… [inaudible]	Addressed Dmitriv
Mr. Patrick	The Pescadores foundation… the fishermen are interested in selling cooked fish but they do not have a way to cook in the solar oven. So we... Why are we doing this?	Addressed Lebron
Lebron	So that they can improve their quality of life and [inaudible]	

Table 5 Conversation between Ms. Natasha and her students during the last day of the unit in lesson 12

Speaker	Content	Observation/code
Ms. Natasha	Ladies and gentlemen...how important is it the client is from Ecuador	Initiating
Student 1	I don't know.	Responding And a few others also blurted.
Student 2	Not really	Responding And a few others also blurted.
Student 3	Not that important	Responding Smiled at the camera
Ms. Natasha	Why not?	Evaluating and initiating
Student 3	Because errrr. We don't exactly care. We're just trying to make the *things	Responding *moved fingers in a wavy pattern and smiled
Ms. Natasha	Okay. how many people agree with YES?	Evaluating and initiating (one hand was raised)
	I want you to be honest. There's no right or wrong answer. I'm just curious.	
	Okay how many people… is there anyone disagree the client is from Ecuador?	
	Alright, Martha? Why do you disagree?	
Martha	Coz they might have do something [inaudible] … scam	Responding
	It's important that the client is from Ecuador so it's a real truthful thing.	
Student 4	Oh wa:::it. Are we actually helping people in the world or [are we just doing this for fun?]	
Ms. Natasha	[*Yeah* alright number three. What problems is the client trying to..	Evaluating and initiating *spoke soft and extremely fast*
	Oh do we have another question or two?	
Student 5	yeah.	Responding
Ms. Natasha	okay	Evaluating
Student 5	Um. Like it matters because it depends on what kind of fish they're trying to cook and stuff.	Responding
Ms. Natasha	Okay so it gave us background knowledge [on how we should cook it?]	Evaluating
Student	[We should have cooked these fish]	
Ms. Natasha	*soft giggle*	
	Any other thing? Number 2. Why is it important that the client is from Ecuador? So either important or not important. Does anybody else have anything to say about this one?	Initiating
	Okay third one. What problem is the client trying to solve?	

that these students should conduct their own research to learn more about the *Others* to get a better understanding of who they are, what they do, and what problems they may have. To overcome the misrepresentation of cultures in the curriculum, Mr. Patrick could have allowed his students to do research on Ecuador or shared more information about Ecuador with his students.

Unlike Mr. Patrick, Ms. Natasha barely talked about the Ecuadorian fishermen until the very last day where she asked her students about those fishermen in greater details. Her lessons were limited to the problems they were tasked to solve. Even so, during the first lesson where she showed two video clips of Ecuador and its fish market, Ms. Natasha called Ecuadorian fishermen as either "fishermen" or "they," thus, distancing herself from the Ecuadorian culture. Interestingly, she also did not mention helping Ecuadorians to have a better way of life. As a result, many of her students ended up perceiving the engineering design challenge through the task itself, not who the client was. Upon being asked by Ms. Natasha about how important it was that the client came from Ecuador, most of her students did not think Ecuadorian context was that important, thus, being indifferent to the *Other's* culture. Their responses aligned with the commonly perceived thing-oriented aspect of engineering design (Bairaktarova & Pilotte, 2020) and illustrated how little they cared about the underlying Ecuadorian context. There was no opportunity for students to empathize with the Ecuadorian client and end-users. Students were fixated on designing solution to the problem based on the criteria and constraints. Kumashiro would argue that the avoidance of discussing the culture and people embedded in the curriculum is analogous to enforcing an oppressive education. To overcome the oppression, Ms. Natasha could have occasionally

Table 6 Conversation between Ms. Natasha and her students during the first day of the unit in lesson 1

Speaker	Content	Observation/code
Ms. Natasha	How many people have been to Ecuador or somewhere in that area?	Initiating
Students	(no hands were raised)	Responding
M.s Natasha	Me neither. (.) We're going to do some research.	Evaluating
	We're going into the fish market	Showed video to students and talked to them simultaneously
Students	Woaaaah!	
Student 1	I like fishing	
Student 2	It smells bad	
Ms. Natasha	What do you see?	Initiating
	See...they're butchering the fish right there. (.) I'm sure that seals smells the fish. But they're right next to water, right?	Saw seals and fish in the video.
Student 3	Hey fishy!	Responding Saw fish
Ms. Natasha	These are pretty big fish, right?	Evaluating
Student 4	They allow you go out on boat?	Responding (with question)
Ms. Natasha	That might be the fisherman.	Evaluating
	You can see they're keeping the fish in this container, right?	
	Okay. So we're going to look at the letter. (.) Can I get a volunteer to read?	
	Alright, one second. So let's make sure….what are we doing?	Initiating
Student 5	We're making a...we're trying to make a small solar oven for them to help cook fish	Responding
Ms. Natasha	Why are they trying to cook fish?	Evaluating and initiating
	So they'll be easier to sell (.) So they're trying to make more money, right?	

referred back to the Ecuadorian fishermen end-users and allocated some of the class time for her students to discuss about their privileges and positionalities that come with living and going to schools in the USA. That way, there would be opportunities for students to develop empathy and to think about people from other countries. According to Kumashiro (2002), this would raise students' awareness of and lead them toward developing empathy for the *Others*.

When it comes to STEM curricula that represent the *Others*, not teaching about *Otherness* and teaching about *Otherness* in a misrepresented way are both harming the students and they influence students' perception of the *Others*. Students in Mr. Patrick's class expressed an elitist, deficit-based, and a narrow view of the Ecuadorian fishermen reflecting both the client letter's language and how Mr. Patrick himself implemented the unit. On the contrary, many students from Ms. Natasha's class were indifferent toward the *Others* as conversations surrounding the Ecuadorian fishermen were very limited. Since the curriculum utilized information about the *Others* as the client who introduced the problem, emphasis should also be about the *Others*. Students should be given opportunities to conduct their own research on the *Others* throughout the unit and discuss their findings as an entire class, which could include reflecting upon their own positionality with respect to the *Others*. This would align with Kumashiro's third tenet of anti-oppressive education: education that is critical of privileging and *Othering*.

One common stereotypical example is the perception that people from developing countries need help from us—financially and materially. The non-profit organization context may have solidified the aforementioned perception. Both Marie and Tamya from class A stated how learning about Ecuadorian fishermen had opened their eyes to donate to those who need help. Specifically, Marie called out "donating to other countries and places that don't have the good things like we do." This was echoed by Tamya's statement: "I know other people struggle and need help". Donating to help people from developing countries is not the same as donating to help natural disaster victims from developing countries. While both cases are centered on human-focused needs and display a good intention of giving, there are subtle differences between the two. In the first case, it is not known if people from developing countries need help. By donating to them, a society where people from developing countries depend on others' generosity to live may be created. To illustrate this point, Moyo (2009) wrote an article about why foreign aid is hurting developing countries like those in Africa and shared how the governments' reliance on foreign aid impeded their

country development through cycles of corruption and briberies as they had no incentive to improve their citizens' lives. Specifically, the "aid to Africa has made the poor poorer, the growth slower. The insidious aid culture has left African countries more debt-laden, more inflation-prone, and more unattractive to higher-quality investment" (p. 2). On the contrary, it is more likely that people who were affected by natural disasters need all the help they could get. Furthermore, some students may find stereotypes portrayed in the written curriculum offensive. This makes it even more important for instructors to appropriately present the Ecuadorian culture, spend time addressing the misconceptions students have about the *Others*, and encourage students to always question what is said and left unsaid. That way, education would promote changes in perceptions of students and society.

Implications

This study has many implications for practitioners. First, teachers may not realize that the underlying cultural context behind STEM lessons can lead to deficit-based views, thus, contributing to the stereotypes and disrespect of other people. Because of this, the teachers then play a crucial role in selecting and implementing the curriculum so students would not fall victim to the "well meant failures of the teachers" (Claydon et al., 1977). Engineering is driven by problems (Mitcham & Muñoz, 2010) which can lead to a deficit-based view of communities and people, rather than as asset-based approached advocated by many education researchers (Gay, 2013; Ladson-Billings, 1995; Moll, Amanti, Neff & Gonzalez, 1992). Thus, we argue that given any curriculum, it is the teachers' role to critically examine the written curriculum that is being implemented in their own classes, especially by evaluating how it portrays those who have been *othered* and oppressed. Teachers and educational practitioners can work toward anti-oppressive education by becoming critical reviewers of the curriculum, textbooks, and other class-related materials such as video and audio content before they carry out their lessons. If the curriculum includes context about *Otherness* to situate learning, it is imperative for teachers to conduct their own research on the *Others* before implementing the curriculum. This is to ensure that their bias knowledge of the culture in the curriculum is modified. Within the lessons themselves, instructors should provide ample time for students to reflect upon their own privileges and question what is left unsaid by the curriculum and the teacher to have an education that changes students and society (Kumashiro, 2002).

Second, because we are living in a globalized world, it is essential that students are educated and molded into global citizens who not only care about themselves but also care and empathize about others. Teachers should provide adequate time for class discussion to learn more about the underlying cultural context associated with the stakeholders and clients of the engineering design. To help students think about and perhaps empathize with those who are marginalized, some guiding questions provided in Mitcham and Muñoz (2010) such as: "Who benefits and who pays? Who stands to gain or lose? Who says who needs what and when? Who is contributing to the design and implementation? And how will the project be sustained" could also be asked during STEM class involving engineering design. That way, the lessons can be both about STEM and the *Others* (Kumashiro, 2002). Teachers also have to explicitly state that culture changes all the time and what is shown in class is just one aspect of culture in a moment in time.

Not teaching about these certain cultures is as harmful as teaching about certain cultures in a limited way and ending up misrepresenting them. We cannot separate science from culture when science itself is an amalgamation of cultural knowledge. The modern science we know is a remnant of colonialism, dominantly influenced by the Western culture and is rooted back to the Renaissance (Iaccarino, 2003), the period where Newton and Galileo based their discovery on empirical evidence. Some call for a place-based approach to education (Gruenewald, 2003) utilizing what the local community has to offer and building strong relationships between the community and the learners. Others might advocate for place-based education (Sobel, 2004), which is defined as "the process of using the local community and environment as a starting point to teach concepts" (p. 4), in their classes. We, on the other hand, encourage teachers to go above and beyond, and teach about world culture on top of the required science standards. There are many benefits associated with making STEM education, human-centered or person-oriented.

Conclusions

This work highlights the importance of curriculum context behind students' learning in STEM-related subjects and the need for teachers to develop expertise in incorporating and implementing global culture in their classrooms in anti-oppressive ways (Kumashiro, 2002). Our findings illustrate that students develop or solidify certain beliefs about people, places, and ways of life represented in the curriculum. The limited portrayal of these cultures is harmful for students especially if cultures are being treated as static and a foundation for stereotypes about certain groups. In this study, students ended up perceiving the Ecuadorian context from an elitist view, deficit-based view, and/or indifferent view. Despite several students being indifferent toward the Ecuadorian fishermen context, we think it is important to include

cultural contexts in STEM lessons to situate the learning, to make learning meaningful, to include the *Others*, and to educate about them. Although there are risks associated with misrepresenting these cultural contexts, if done right, students would be a step closer toward becoming global citizens in this age where everyone is just a click away from each other. To make these cultural contexts appropriate for STEM lessons, the teachers need to critically examine, evaluate, and modify the contexts accordingly prior to their implementation. Instructors should also provide adequate means for students to learn about places, people, and their ways of life beyond what the curriculum offers. Future work could compare and determine the effect on students' learning between place-based (Sobel, 2004) and global education.

Supplementary information

Supplementary information accompanies this paper at https://doi.org/10.1186/s40594-020-00224-5.

Additional file 1. The client letter introducing the grand challenge.

Additional file 2. Classroom conversations have been transcribed based on the following conventions, adapted from Rapley (2001).

Abbreviations

STEM: Science, Technology, Engineering and Mathematics; RQ: Research question; NGSS: Next Generation Science Standards; EiE: Engineering is Elementary; NSF: National Science Foundation

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