STEAM AND INCLUSIVITY: ENGAGEMENT AND BEST PRACTICES

Review of equity and inclusion within the STEAMCity project

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This review aims to compile suggestions to increase the inclusiveness and equity of the outputs of the STEAMCity project, considering end participants. Although general suggestions will be provided for different sources of inequality and exclusion (e.g., socioeconomic level, gender, sexual orientation, religious beliefs, physical or intellectual disabilities, race), a particular focus will be placed on gender-inclusive practices.

GENERAL CONSIDERATIONS FOR THE CLASSROOM INQUIRIES

The consortium has designed a collection of classroom-oriented 25 inquiries and experimentation protocols that has been reviewed in their English version available at: https://github.com/steamcity/inquiries/tree/main/all-inquiries. The STEAMCity inquiries are designed to be hands on, problem-based, and highly engaging. They aim to connect abstract scientific and technological concepts to real-world issues, fostering critical thinking, creativity, and collaborative problem-solving among students.

The general approach of this report is structured around two fundamental axes: promoting integration and fostering social justice within STEAM education. By focusing on practical application and authentic challenges, these inquiries seek to make STEAM accessible and relevant to a diverse range of learners, encouraging them to see themselves as active participants in scientific and technological advancements.

Promoting Integration

Each student with a disability has very specific needs, making it impractical to address all individual cases in this report. Hence, the integration suggestions are based on the Universal Design for Learning (UDL) framework. UDL provides a flexible approach to curriculum development that aims to meet the needs of all learners, minimising barriers and maximising learning opportunities. From this framework, each user is expected to add specific requirements if needed.

The three core principles of UDL are:

1. **Provide Multiple Means of Representation**: When possible, present information and content in different ways to suit various learning styles and sensory preferences, such as formats (visual text, audio explanations, simplified language versions), additional visual aids (diagrams, concept maps, images etc. to illustrate complex concepts), glossaries and scaffolding, and/or multilingual support.
2. **Provide Multiple Means of Action & Expression**: When possible, offer learners varied ways to demonstrate what they know and master skills, such as varied grouping (working individually, in pairs, in different groups…) and flexible response options, allowing students to demonstrate their understanding through different mediums.
3. **Provide Multiple Means of Engagement**: Stimulate interest and motivation for learning by tapping into learners' interests, offering choices, and fostering collaboration. For example, promoting collaborative learning and feedback, among others. This aspect is also connected to the suggestions regarding the promotion of social justice in STEAM education.

Promoting Social Justice in STEAM Education

Minoritized collectives in STEAM education, based on factors such as gender, socioeconomic level, race, and others, often experience a negative positioning towards STEAM. If an individual does not feel identified with STEM—that is, connected not only with the people who dedicate themselves to it but also with the type of STEM practices in which they are asked to participate—they are far less likely to engage, succeed, or consider STEM as a future option.

These recommendations aim to ensure that the objective is not solely the promotion of professional vocations. While it is important to have diversity among future STEM professionals, research also highlights the importance of guaranteeing adequate development of STEM literacy for all students and their capacity to enjoy STEM practices throughout compulsory schooling. This means that all students, regardless of whether they want to be scientists or engineers, should be able to understand the world around them from a scientific perspective, participate in informed debates, and enjoy scientific culture.

One of the most influential factors in the construction of these identities is the comparison students make between their personal attributes and the attributes socially ascribed to the STEM field and its professionals. This social image is heavily stereotyped, and its attributes are deeply ingrained in students' perceptions. Among other aspects, numerous studies show how STEM activities or disciplines are considered very difficult (especially physics, according to Archer et al., 2017, or computer science, according to Wong (2017) and disconnected from the real world. These characteristics impact the image of the STEM professional, who is perceived as hardworking, dedicated, and serious, highly intelligent, with a very deep understanding of content, even possessing innate talent, and who deeply enjoys doing or learning STEM (Archer, 2013). This often leads to them being seen as eccentric, peculiar, obsessed with their work, socially awkward, and outside the norm (Archer et al., 2013; Wong, 2017).

To promote greater social justice, the following general considerations should guide the implementation of STEAMCity inquiries:

- **Show the Relevance of STEM in Daily Life**: It is fundamental that students see the utility and application of sciences beyond the classroom, connecting abstract concepts with their reality.
- **Foster Significant Success Experiences**: It is crucial for students to experience success in STEM activities. This does not mean everything should be easy, but rather that they must have opportunities to overcome challenges and see the results of their efforts. It is necessary to break down complex inquiries into smaller, manageable steps, allowing students to achieve success at each stage.
- **Utilize Formative and Formative Assessment**: Use assessment not only for grading but also to provide constructive feedback that helps students improve and believe in their capabilities. More inclusive and metacognitive assessment can have a very positive influence on the generation of STEM identity (Tan et al., 2013).
- **Address Low Self-Efficacy in Girls**: Research shows that many girls, despite high performance in STEM, exhibit low self-efficacy (Archer et al., 2013; Chan, 2022). It is fundamental that educators actively encourage them, make their successes visible, and challenge the notion that "brilliance" in STEM is innate or exclusive to one gender. It is necessary to reinforce that effort and perseverance are key (OECD, 2023).
- **Acknowledge the Crucial Role of Recognition**: As educators, our explicit support and valuation of students' STEM skills can have an enormous impact on their identity. If the community perceives a young person as "hardworking" or "brilliant" in STEM, they will more easily develop a positive STEM identity. Ensure that girls' successes in STEM are equally recognized and celebrated, not just boys. Again, this is especially important for girls from clusters who, despite their performance, feel little recognition in this field. Research shows that a lack of recognition can lead to the denial of less powerful identities, perpetuating exclusion (Archer et al., 2018; Riedinger & Taylor, 2016).
- **Challenge the Stereotypical Image of STEM**: Actively work to dismantle the image that STEM is "very difficult" or "disconnected from the world." Practical activities, real-world problem-solving, and connection with the environment can help change this perception.
- **Foster Compatibility with Other Ways of Being**: Help students see that their interests in arts, languages, or sports are not incompatible with STEM. In fact, many future professions will be hybrid and will require knowledge from different fields.

SPECIFIC CONSIDERATIONS FOR EACH CLASSROOM INQUIRE

For each inquiry, a specific review was conducted to ensure maximum equity and inclusion. This detailed analysis should apply the general recommendations to the particular context of each inquiry. This process involves:

- **UDL Checklist Application**: Systematically review of each inquiry against the three UDL principles (representation, action & expression, engagement) to identify areas for improvement or adaptation.
- **Stereotype Challenging Opportunities**: Identification of how each inquiry can actively challenge common STEM stereotypes, either through its content, proposed activities, or suggested discussion points. The analysis of the inquiry's language, examples, and activities focuses on identifying potential gender stereotypes or biases, aiming to ensure gender-neutral scenarios and characters or a diverse representation of genders.
- **Other aspects regarding the promotion of social justice in STEAM**: Evaluation of the extent to which each inquiry connects to diverse cultural backgrounds or contexts, or if it can be adapted to be more culturally responsive. Assessment of how strongly the inquiry links to daily life and societal issues.

Applying these criteria will enable to include specific considerations to each inquiry, ensuring that the STEAMCity project truly embodies its commitment to integration and social justice. The following pages highlight the most relevant recommendations regarding each specific consideration, based on the nature and development of the protocols

Inquiry - AI Odissey Datawalk

UDL Checklist Application	This activity relies on observation skills. Teachers should consider providing alternative methods for students with observational difficulties to acquire information, such as offering pre-collected data, detailed descriptions, or multimedia resources. Furthermore, guidance should be provided on how students can obtain information regarding sensor ownership, data collection purposes, and usage, especially in contexts where such information may not be readily available. Teachers could suggest reputable public databases or local government resources as sources.
Stereotype Challenging Opportunities	Teachers should encourage students to critically examine their preconceived notions about individuals involved in the use and data processing of urban sensors. This includes challenging biased representations, such as the stereotype of a white male behind a computer. Organizing a visit to a data center or inviting diverse professionals from the field to speak could further challenge these stereotypes. Teachers can also emphasize the collaborative nature of the data walk and the importance of teamwork in identifying and analyzing sensors, highlighting that STEM involves strong interpersonal skills.
Other aspects regarding the promotion of social justice in STEAM	Teachers should consider the applicability of this protocol to students from diverse geographical backgrounds, including rural or semi-rural settings, by exploring the presence and types of sensors in these environments. Additionally, discussions should address the biases inherent in facial recognition and detection technologies, and strategies to mitigate misidentification, particularly concerning marginalized groups. Teachers should also encourage students to discuss how sensor placement might reflect social or economic patterns in their city, fostering critical thinking about urban inequalities and the equitable distribution of technology.

Inquiry - Bio-Inspired Learning Processes

UDL Checklist Application	When utilizing the 6x6 grid game, teachers should offer diverse formats for engagement, such as drawing the board on the floor for kinesthetic learning or providing physical cards for students to mark obstacles. For students with low vision, adaptations such as enhanced visual contrast, larger game elements, or sound interactions with objects (in both human and AI versions of the game) should be considered to facilitate participation and understanding of trial-and-error processes.
Stereotype Challenging Opportunities	In the concluding reflection, it is important to acknowledge the human element behind AI development, including programmers and supervisors. Teachers should emphasize the necessity of human moderation in self-regulated AI learning, highlighting that AI development is a collaborative process that benefits from diverse human input. Teachers can also challenge the stereotype that STEM is "very difficult" by highlighting that the "trial and error" process, which is central to both human and machine learning in this protocol, is a natural and effective way to learn, making complex concepts accessible through iterative attempts.
Other aspects regarding the promotion of social justice in STEAM	In the final discussion, teachers should encourage students to consider various real-world contexts for adaptation (e.g., new school environments, different countries) to appeal to the diversity of student experiences. This approach helps students identify instances where reinforced learning occurs in different settings, promoting a broader understanding of its applicability. Teachers should facilitate discussions that compare human intuition and adaptability with machine learning, encouraging students to recognize that diverse ways of thinking and problem-solving (including those from non-traditional STEM backgrounds) are valuable and contribute to innovation.

Inquiry - BirdSong AI Explorer

UDL Checklist Application	For activities involving auditory components, teachers should provide visual representations of sound waves or spectrograms to ensure students with hearing difficulties can also participate effectively in sound identification tasks. Teachers should provide multiple means of representation for bird identification, including visual images of birds or written descriptions of their characteristics, to accommodate different learning preferences.
Stereotype Challenging Opportunities	Teachers can challenge the stereotype that STEM is "disconnected from the real world" by emphasizing how AI tools for birdsong recognition directly contribute to real-world conservation efforts and help monitor urban biodiversity, demonstrating the practical impact of technology. Mapping bird observations can be utilized to estimate species populations, connecting to biological topics such as ecosystem equilibrium. Discussions can address how imbalances (e.g., excessive bird populations) can lead to increased disease transmission, pests, infrastructure damage, or ecological imbalance. Linking these biological topics allows students to understand the purpose of the activity beyond AI tool development, fostering a sense of environmental stewardship and demonstrating how technology serves communal and personal goals.
Other aspects regarding the promotion of social justice in STEAM	Teachers should consider the diverse urban environments from which students originate, including coastal cities with significant seagull populations. Discussions can explore how urban districts with lower socioeconomic status may exhibit reduced species richness, leading to "biological poverty" and diminished sensory stimulation. Furthermore, teachers should account for seasonal variations in bird populations due to migration patterns, such as the presence of swallows at different times of the year, ensuring the protocol remains relevant regardless of the implementation period.

Inquiry - Bot Buddy Adventure

UDL Checklist Application	Given that this activity's application can significantly benefit individuals with visual impairments, teachers should explore strategies to engage these students in the design process, such as integrating an AI assistant to aid in chatbot coding. To ensure the final product is meaningful and useful for diverse end-users, their inclusion in the development process is crucial.
Stereotype Challenging Opportunities	Teachers should incorporate examples of emergency scenarios, such as navigating to a health center or police station, to highlight the practical applications of chatbots. Dedicated time should be allocated to discuss the ethical implications of speech recognition and data storage, including privacy concerns. Seeking parental consent for student participation in activities involving personal data is also advisable. Teachers can challenge the stereotype that STEM is only for "highly intelligent" individuals with "innate talent" by emphasizing that the iterative process of testing and refining the chatbot, including handling errors and improving accuracy, is a key part of STEM work that relies on perseverance and problem-solving, not just innate brilliance.
Other aspects regarding the promotion of social justice in STEAM	Teachers should consider the specific needs of diverse populations, such as students from varying socioeconomic backgrounds, elderly residents, or non-native speakers, when designing chatbots. This approach highlights the social impact of technology and its role in creating more inclusive urban environments for all citizens.

Inquiry - City Detective Challenge

UDL Checklist Application	To address the potential complexity of crisis scenarios for some students, teachers should provide simplified situations for initial training and/or offer specific scaffolding. This support should enable students to progressively develop their own protocols for addressing critical considerations during emergencies.
Stereotype Challenging Opportunities	To enhance the applicability and meaningfulness of the proposed solutions, teachers should encourage students to connect the activity's outcomes with potential implications for their own city or town. Discussions should focus on lessons learned from the simulation and culminate in the elaboration of improvement suggestions for relevant administrative bodies.
Other aspects regarding the promotion of social justice in STEAM	For students from lower socioeconomic backgrounds who may perceive public and administrative spaces negatively, teachers should consider incorporating non-formal spaces (e.g., neighborhood associations, NGOs) that resonate more meaningfully with their experiences. This fosters a more inclusive and relatable learning environment.

Inquiry - Data vs. Context: The Citizen Challenge

UDL Checklist Application	To mitigate the abstract nature of working with diverse datasets, teachers should consider ordering and presenting data to students from the simplest to the most complex, facilitating progressive success in achieving the challenge. Additionally, teachers should provide various methods for students to engage with data, such as utilizing visual aids (whiteboards, sticky notes, A3 sheets), to cater to diverse learning and expression styles.
Stereotype Challenging Opportunities	When discussing data-oriented careers depicted in the activity's description, teachers should engage students in conversations about the real-life implications of these roles. A particular focus should be placed on challenging common stereotypes by highlighting the diversity of individuals represented in these professions (e.g., "Did you imagine a data engineer in this way? How did you imagine them?"). Teachers can also emphasize that "data literacy" and "critical data analysis," central to this protocol, are skills developed through hands-on, gamified activities, making data science accessible and enjoyable for all students regardless of their perceived innate ability.
Other aspects regarding the promotion of social justice in STEAM	Teachers should consider providing a real-life example of a completed activity for Step 3 (data vs. context, emphasizing the importance of contextualization). This approach can enhance the relevance of the activity by demonstrating its practical application.

Inquiry - Decibel Detectives

UDL Checklist Application	Teachers should acknowledge that students with hearing difficulties may not experience issues with noise volume but might struggle with message comprehension due to noise. Adaptations should be considered ensuring clear communication of instructions and information.
Stereotype Challenging Opportunities	Teachers should facilitate discussions about the roles of professionals responsible for building noise insulation (e.g., architects, technical architects, acoustic consultants). Students should be encouraged to envision these individuals, challenging stereotypical biases and emphasizing the diversity and equity within these professions. Teachers can also emphasize the collaborative nature of designing and conducting the noise study, highlighting that scientific inquiry involves teamwork, communication, and understanding of human experiences.
Other aspects regarding the promotion of social justice in STEAM	Teachers should encourage students to investigate potential solutions to identified noise problems, particularly focusing on effective wall and window insulation materials. Engaging students in a campaign to secure funding for classroom insulation to improve well-being could be considered. Discussions should also address the broader implications of high noise levels, such as the correlation between external traffic noise and indoor air pollution, and its potential impact on students' cognitive and mental abilities.

Inquiry - Ecological Impact of Mobility Regulation

UDL Checklist Application	To ensure equitable participation, teachers should not only promote the formation of teams with diverse skills and knowledge area preferences, but also assign specific roles to students. These roles (e.g., context provider, note-taker, communication strategist, conceptual problem analyst) should ensure that all participants contribute meaningfully to the group's projects. Teachers should provide visual diagrams and step-by-step guides for Roobokart assembly and C++ code structure, alongside verbal explanations and opportunities for hands-on experimentation, to cater to various learning styles.
Stereotype Challenging Opportunities	It is crucial that these assigned roles are recognized as equally valuable contributions to project development, as recognition is key to fostering students' STEM identities. Where feasible, teachers should promote the rotation of roles among group members to provide each student with experience across different tasks. Discussions can explore various leadership styles (e.g., democratic vs. authoritative), examining how these styles influence student feelings and participation in group decision-making, particularly noting that girls often thrive in more democratic environments. Teachers can also emphasize that collaborative problem-solving within the hackathon, including debugging and iterative improvement of the Roobokart code, highlights perseverance and teamwork as crucial STEM skills, not just individual brilliance.
Other aspects regarding the promotion of social justice in STEAM	Teachers should endeavor to configure the smart city simulation to closely resemble the students' own city or town. This approach allows hackathon outcomes to be easily applied to real-life scenarios, enhancing the relevance of the activity and its potential to improve students' quality of life. Teachers should encourage discussions about how autonomous vehicle design and mobility regulations can address real-world urban challenges such as reducing pollution, improving public transportation accessibility for all citizens, and fostering equitable urban planning, thus connecting engineering solutions to social justice issues.

Inquiry - Energies in perspective. Understanding energy and its sources

UDL Checklist Application	When students enter secondary school, they have often heard and used the term "energy" in various contexts, from scientific disciplines to everyday life, and even in areas like magic. Despite its widespread use, many do not grasp its specific meaning, especially within physics. This leads to common misconceptions that can be grouped into three main categories (López-Simó & Couso, 2024). • Many students view energy as a fluid that permeates physical objects and passes through them, especially through tubes, cables, and other conduits. This imaginary fluid can be stored and transferred, remaining inactive and then activating for a specific occasion, for example, within batteries or energy foods. This idea has a sociocultural origin and often stems from fictional portrayals of powers and rays. • Energy is frequently seen as a synonym for life and activity. Students are said to have "a lot of energy" because they are active, while older people have "little energy." This vitalist view leads to misconceptions, such as believing inanimate objects lack energy or associating energy solely with movement. • Some perceive energy as a driving force that causes changes, akin to "the go of things." However, physics emphasizes that energy is not the cause of change, but a way to describe and quantify it by comparing "before" and "after" states. For effective learning, educators should encourage students to express these existing conceptions and then guide them to understand the limitations of these views, focusing on observable changes rather than absolute values or causative forces.
Stereotype Challenging Opportunities	Step 3 introduces a compelling projection exercise, prompting students to explore the consequences of a specific energy source's absence. While effectively highlighting our dependence on various energy forms, this activity could inadvertently foster a negative future outlook. Given that some students may experience eco-anxiety, potentially fueled by perceiving STEM as the primary cause of environmental issues (because of historical reliance on fossil fuels for technological development), teachers should conclude the activity with a crucial discussion. This discussion should emphasize STEM's vital role as part of the solution, showcasing examples of sustainable innovations like advanced solar technologies, energy storage solutions, and tidal and wave energy. Furthermore, it is important to clarify that the limited adoption of these innovations is not solely a STEM issue. Instead, economic and societal constraints often impede their widespread implementation. Illustrating this point with historical examples from science, such as Barbara McClintock's theories on "Transposable Elements" or Ignaz Semmelweis's work on "Cadaveric Particles" and handwashing, can provide valuable context on how revolutionary ideas face societal and institutional barriers, not just scientific ones.
Other aspects regarding the promotion of social justice in STEAM	This protocol aims to integrate key energy topics: the imperative of achieving energy justice and fostering an energy transition that balances environmental, social, and economic needs. It is especially crucial that discussions with students on complex research questions—such as "What social inequalities and injustices are created or reproduced by contemporary energy choices?" and "How can we reconcile environmental, social, and economic imperatives in energy transitions?"—move beyond theoretical answers. These questions have direct consequences for our lifestyles. To help students grasp this complexity, avoid oversimplification, and ensure the analysis moves beyond a purely theoretical level, teachers might consider engaging them in classroom dynamics. Games like "a 10 torns del col·lapse" (in Catalan) or "Sustainable Energy Transition Strategy", can be highly beneficial complements to the protocol. It is also important that, in addition to reflecting on different energy sources, students discuss questions like: "How did you feel during the game?", "Do you think the situation presented is plausible?", "In reality, how could we help mitigate the problem of resource scarcity?", "What do we need to learn to provide solutions?", "Do you think the population is aware of the problem?"… etc.

Inquiry - Energy Mix Simulator. Exploring the Paths of Energy Transition

UDL Checklist Application	Teachers may consider problematizing the step 1 (Deciphering the energy mix) to evidence to students why analyzing the logic of electricity system can be important to understand how their country work. The recent, well-documented April 28, 2025, blackout across the Iberian Peninsula (Spain and Portugal) can provide a rich, real-world case study for analyzing energy mix challenges. Moreover, it may allow students to delve into technical, economic, and societal aspects. Afterwards, they can analyze their own country's energy mix and try to guess the possible consequences of a similar scenario.
Stereotype Challenging Opportunities	The development and experimental application of energy transition models across various scenarios represent a conceptually demanding and abstract undertaking. Teachers might consider concluding the activity with a discussion of the stakeholders responsible for elaborating these models and testing potential solutions within each nation. It is beneficial to underscore that this process is complex and multi-layered, involving a diverse range of actors rather than a singular entity. This collaborative ecosystem necessitates extensive interdisciplinary cooperation to construct such intricate models, thereby emphasizing the inherently collaborative nature of STEM development.
Other aspects regarding the promotion of social justice in STEAM	To underscore the social justice dimension, teachers are encouraged to facilitate a culminating discussion centered on critical aspects like the health impacts of energy sources and the fair distribution of benefits in energy production. For example, analysis of health impacts can explore how fossil fuel power plants, mines, and refineries are frequently situated in proximity to low-income communities and communities of color. The resulting pollution from these facilities is linked to elevated incidences of asthma, cancer, and other health disparities among residents, thereby raising questions of environmental racism. Conversely, a focus on the fair distribution of benefits highlights that energy justice encompasses not only mitigating harm, but also ensuring equitable access to the advantages of the energy transition. This includes fostering community-owned renewable projects where profits directly benefit local populations or implementing programs that reduce energy costs for low-income households through energy efficiency improvements. Such a debate can naturally prompt students to examine the democratic mechanisms available to citizens for influencing energy choices, as outlined in the protocol.

Inquiry - Factbusters

UDL Checklist Application	Teachers should provide diverse resources for students to analyze in Step 1 (e.g., articles, videos, images). Furthermore, a variety of methods for students to present their fact-checking protocols should be offered, including traditional formats like poster making and oral presentations, in addition to creative digital tools.
Stereotype Challenging Opportunities	Teachers can challenge the stereotype that STEM is "disconnected from the real world" by explicitly linking the "FactBusters" activity to real-world issues of fake news and misinformation, demonstrating how scientific literacy is crucial for informed citizenship and navigating complex societal challenges. While developing critical thinking is paramount, it is also valuable to discuss how scientific information and evidence can evolve. This approach acknowledges that scientific knowledge is not always objective, neutral, and immutable, thereby challenging stereotypes about scientific activity without diminishing trust in the scientific method.
Other aspects regarding the promotion of social justice in STEAM	Teachers should consider that myths testable with school-available materials might be simplistic. Emphasis should be placed on developing students' skills in evaluating evidence quality, enabling them to apply various criteria to verify information retrieved from the internet. The C.R.I.T.I.C. questionnaire (Oliveras et al., 2013), designed to guide critical analysis of scientific news, can serve as a valuable tool for developing fact-checking protocols: https://www.tandfonline.com/doi/abs/10.1080/09500693.2011.586736)

Inquiry - Flower Guardians. Pollinator tracking

UDL Checklist Application	Given the significant field data gathering component of this protocol, teachers should offer flexibility in grouping arrangements (e.g., individual work, pairs, diverse groups). This ensures students feel comfortable, streamlines logistical aspects of commuting, and allows for coverage of a broader urban area.
Stereotype Challenging Opportunities	Teachers can challenge the stereotype that STEM is "disconnected from the world" by highlighting how the "Flower Guardians" activity directly contributes to real-world environmental conservation efforts, demonstrating that scientific inquiry can be applied to local ecosystems and have a tangible impact on biodiversity. This activity encompasses content from engineering/technology, mathematics, and science, which may elicit varying levels of interest among different genders. When working in groups, teachers should promote rotational roles to ensure equitable opportunities for participation across all activity areas. Additional scaffolding may be necessary for Step 3 (data analysis), such as providing examples of different data trends for comparison, using analogies to clarify statistical concepts, and presenting data in various graphical formats to ensure students possess the necessary tools for successful completion.
Other aspects regarding the promotion of social justice in STEAM	While examples are provided in the protocol, teachers should consider incorporating a final application phase to promote the view that STEAM is not only essential for problem analysis but also for solution development. This project can be enhanced by constructing insect hotels or pollinator gardens to increase pollinator populations in urban areas. Discussions should explicitly address the reasons for the environmental impact on pollinator populations, drawing upon students' existing knowledge of living beings and ecosystems. This fosters connections with prior learning and other disciplines, leading to a more integrated understanding of the problem and STEAM.

Inquiry - From Warm Walls to Cool Cities

UDL Checklist Application	To enhance student comprehension of abstract concepts such as air permeability and thermal diffusivity, teachers should minimize the excessive use of mathematical formulas in definitions. Instead, visual aids (e.g., drawings, schemes, pictures, thermal images) should be incorporated to promote an understanding of heat transmission concepts.
Stereotype Challenging Opportunities	When students work in groups, teachers should encourage the rotation of roles (e.g., leader, writer, manipulator) to ensure equitable opportunities for participation in the activity. Given the distinct experimental steps in this protocol, pre-defining and rotating roles can be easily implemented. Subsequent discussions should focus on students' experiences in different roles and their specific contributions to team efforts, challenging the stereotype that STEM is "very difficult" by demonstrating that complex topics can be approached through manageable steps, leading to successful outcomes.
Other aspects regarding the promotion of social justice in STEAM	Teachers should consider engaging students in a campaign to improve the heat retention of public facilities or their schools. This initiative can empower students to perceive STEM as a tool for both problem analysis and solution implementation, serving a communal purpose. Teachers should encourage students to discuss how poor insulation and energy inefficiency disproportionately affect vulnerable populations (e.g., low-income households struggling with high energy bills or health issues due to extreme temperatures), fostering critical thinking about equitable access to comfortable and healthy living environments.

Inquiry - Light vs. Zzz. The Great Sleep Battle

UDL Checklist Application	Teachers should offer diverse methods for students to present their findings across various phases, including infographics, storyboards, visual narratives, video summaries, or animations, in addition to mind maps. This protocol can be effectively linked to the "SoundSquad: Sensitive Mapping of Noises" protocol as a continuation or precede "The Great Sound Escape: Investigating the Sound of Silence" protocol, establishing interdisciplinary connections.
Stereotype Challenging Opportunities	Teachers should explicitly emphasize the connection between technology and health, which can particularly engage students who typically feel disengaged from technology due to its perceived focus on machines. Highlighting the relevance of health sciences can increase student engagement and alter their perception of engineering and technological purposes. Teachers can challenge the stereotype that STEM is "obsessed with work" or "socially awkward" by emphasizing that understanding sleep science, a topic directly related to personal well-being, involves interdisciplinary thinking and collaboration, demonstrating that STEM can be applied to improve quality of life and is a field that values holistic understanding.
Other aspects regarding the promotion of social justice in STEAM	Teachers should consider that bed quality can also influence students' sleep quality. The protocol should allow for the inclusion of additional indicators relevant to students' contexts or those they wish to investigate. Teachers should encourage students to explore how urban pollution (light, noise, temperature) and technological habits (screen use) might disproportionately affect sleep quality in different communities (e.g., neighborhoods with higher light/noise pollution, or varying access to technology), fostering discussions about environmental justice and equitable access to restorative sleep.

Inquiry - Monitoring Indoor Air Quality

UDL Checklist Application	While the provision of both visual and detailed code for specific applications is beneficial, teachers should prioritize engaging students in understanding the core function of the programming blocks utilized.
Stereotype Challenging Opportunities	Teachers should acknowledge and recognize the contributions of all group members, including those who primarily participated in the conceptualization or documentation processes, rather than direct programming. Teachers can challenge the stereotype that STEM is “disconnected from the real world” by emphasizing that building and utilizing a CO2 detector directly impacts students’ immediate learning and living environments, demonstrating how scientific tools can be applied to improve daily health and well-being.
Other aspects regarding the promotion of social justice in STEAM	Teachers should encourage students to discuss how indoor air quality can vary significantly across different building types (e.g., older schools vs. new constructions, public vs. private spaces) and its implications for equitable access to healthy learning and living environments, fostering awareness of environmental disparities. In the concluding discussion, the complexity of situations where external air might also be polluted should be addressed, prompting students to consider the trade-offs between indoor CO2 levels and the presence of other external pollutants if ventilation occurs. This problem can be explicitly linked to the “Monitoring Outdoor Air Quality” protocol.

Inquiry - Monitoring Outdoor Air Quality

UDL Checklist Application	To support students encountering difficulties with abstract reasoning, it can be beneficial to provide visual examples of temporal patterns in data (Step 3–analyzing the data) and specific illustrations of confounding variables or factors that can influence both dependent and independent variables.
Stereotype Challenging Opportunities	Teachers can challenge the stereotype that STEM is “disconnected from the real world” by emphasizing how building and deploying an outdoor air quality monitoring station directly addresses a local environmental issue, demonstrating the immediate and tangible impact of STEM on community health and well-being. Discussions on the health effects of air pollution should be incorporated to underscore the connection between technology and health sciences.
Other aspects regarding the promotion of social justice in STEAM	Where feasible, teachers should encourage students to compare their collected data with official pollution data to discuss the reliability of gathered information. This comparison can also empower students’ contributions when utilizing their data for action. Teachers should encourage students to investigate how air pollution disproportionately affects certain neighborhoods or communities within their city or globally, fostering discussions about environmental justice and advocating for equitable air quality for all citizens.

Inquiry - NegaWatt Scenario and Energy Sobriety. Understanding Energy Through History

UDL Checklist Application	To initiate student engagement, teachers may consider providing graphical examples of diverse energy sources to help students in the analysis of their energy consumption. These visuals should establish a relatable context or serve as a narrative lead, for instance, by illustrating the journey of energy from the moment a student wakes up until they go to sleep. This approach immediately connects abstract energy concepts to their daily lives. Furthermore, it is highly recommended to concretize 'Step 3 - Exploring the Levers of Sobriety' within a specific, tangible context that resonates with students. The school environment offers an ideal setting for this. The analysis should extend beyond just the school building's energy consumption (e.g., lighting, heating, cooling, student commute). This step 3 can be framed as a student-led project, empowering them to conduct research, communicate their findings, and critically suggest possible actions to enhance energy sobriety within their own school community. Furthermore, to accommodate diverse learning styles, teachers should offer various methods for students to communicate the results both in step 3 and step 4 (personal energy habits audit).
Stereotype Challenging Opportunities	To broaden student perspectives, teachers are encouraged to illustrate that energy audits and the promotion of energy sobriety are not merely academic exercises but constitute a dedicated professional field within STEM. This effort transcends school-based demands, engaging a vast array of stakeholders from non-governmental organizations and private enterprises to governmental agencies, and necessitating further widespread involvement. Highlighting the intrinsically interdisciplinary nature of energy audit teams, which integrate expertise from fields such as architecture, engineering, energy management, and environmental sciences, can effectively challenge stereotypical perceptions of STEM careers. This approach critically emphasizes the demand for diverse professional profiles within STEM and underscores the direct connection between engineering and technological disciplines and the pursuit of vital real-world objectives.
Other aspects regarding the promotion of social justice in STEAM	This protocol proposes a critical discussion centered on analyzing historical energy data to understand the mechanisms that have shaped our current consumption patterns. To emphasize the vital social justice perspective within this analysis, teachers should introduce how energy decisions and systems disproportionately affect different people and communities, highlighting the fundamental question of fairness: who benefits from energy, and who bears its burdens? To concretely illustrate this historical trajectory and its ongoing impact, teachers can present specific cases: • The "Not In My Backyard" (NIMBY) Phenomenon: Explain how local opposition to new energy infrastructure, while understandable, has historically led to undesirable energy projects (like fossil fuel plants or waste disposal sites) being pushed into less politically powerful, often marginalized communities. These communities, with fewer resources to fight back, disproportionately bear the environmental and health burdens, thereby reinforcing existing inequalities. This demonstrates how historical energy choices have created legacies of environmental injustice. • Global Energy Inequality and Historical Exploitation: Even as we analyse energy consumption from a European perspective, it's critical to acknowledge that billions of people, predominantly in developing countries, still lack access to reliable electricity or the range of appliances commonplace in European homes. This stark disparity underscores that energy justice is not only about achieving energy sobriety in over-consuming nations but also, fundamentally, about rectifying these profound global inequalities. It is particularly pertinent to discuss how many European countries have historically and continue to largely benefit from the natural resources (including those used for energy production) of these same developing countries, establishing a clear link between past colonial practices, current resource extraction, and the uneven distribution of energy access and its associated burdens today.

Inquiry - Plants & the City

UDL Checklist Application	Prior to data measurement, it is crucial for students to predict the range of expected values. This process, while not solely focused on numerical accuracy, activates prior knowledge and encourages its application to the situation (e.g., “Considering what you know about this plant, have you ever seen it in this location? Why do you think so? What values do you anticipate gathering for light/humidity/temperature?”). Following measurement, a reflective discussion should ensue, comparing gathered values with initial predictions and prompting students to provide reasons for any discrepancies.
Stereotype Challenging Opportunities	Engaging a local gardener or gardening organization in the project can be highly beneficial. While AI tools, botanical books, and specialized databases are valuable for identifying suitable plant species, integrating a gardener demonstrates that STEM knowledge can also be found in these professions, affording them the same status as mainstream STEM products. This approach visibly recognizes the contributions of often-unrecognized popular and service professionals (such as gardeners) to STEM, thereby challenging stereotypes and illustrating that STEM exists beyond the laboratory.
Other aspects regarding the promotion of social justice in STEAM	Students should be empowered to choose the location for their green wall. Discussions should address the sustainability of the project, including strategies to ensure community appreciation and prevent the removal of plants from common spaces. Teachers should encourage students to discuss how urban greening initiatives can address environmental inequalities, such as providing access to green spaces and improving air quality in underserved neighborhoods, fostering an understanding of how technology and environmental science can contribute to more equitable urban environments.

Inquiry - Road Signs of Tomorrow

UDL Checklist Application	Teachers should consider including more detailed scaffolding to assist students in defining their signs, particularly in Step 1. For example, employing a design-thinking strategy would encourage students not only to meet technological requirements for producing more intelligible signals but also to create signs that address an identified need or problem relevant to their specific contexts.
Stereotype Challenging Opportunities	Teachers should engage students in a final discussion regarding the applications of this protocol to autonomous vehicles, emphasizing the necessity of ensuring reliable and rapid data analysis and processing. It is advisable to develop an activity that promotes the development of critical thinking skills concerning the real-world development of autonomous vehicles, exploring their potential and actual outcomes. Beyond emphasizing the STEAM approach, it is crucial to highlight the connection between technological developments and real-life applications to challenge common stereotypes about engineering.
Other aspects regarding the promotion of social justice in STEAM	Depending on students’ age, their familiarity with road signs may vary. Teachers should consider an initial activity involving observation of the surroundings to identify frequently encountered signs and infer their meanings. This can be beneficial for students in identifying needs during the design-thinking phase of their own sign creation. Teachers should also encourage students to consider how road sign design impacts different road users, including pedestrians, cyclists, and individuals with varying visual or cognitive abilities, fostering discussions about inclusive design and equitable access to safe urban infrastructure.

Inquiry - Smart Objects Safari

UDL Checklist Application	Recognizing varying learning rates in students' programming skill development, teachers should offer flexible opportunities for group composition. This includes forming groups with students of similar skill levels or, alternatively, grouping students with diverse skill levels to facilitate peer-to-peer learning and mutual support.
Stereotype Challenging Opportunities	The protocol focuses on the design of smart objects for a smart city. While this objective appeals to many students, teachers should consider broadening it by providing students with the opportunity to conceptualize any object (including domestic ones) that could benefit from being "smart" (i.e., incorporating sensors and actuators). In this regard, an initial step in the conceptualization stage could involve agreeing on a broader mission, such as "designing smart objects that improve our living conditions," rather than solely "designing smart objects that help or hinder self-driving vehicles." This approach challenges the common misconception that engineering and technology primarily involve inventing new, futuristic items. Conversely, it highlights the equally significant task of redefining everyday appliances. In this manner, teachers can challenge the stereotype that STEM is "eccentric" or "peculiar" by emphasizing the practical and creative aspects of designing smart objects that solve real-world problems, demonstrating that engineering and technology are fundamentally about improving daily life for everyone.
Other aspects regarding the promotion of social justice in STEAM	When engaging students in the design process and coding, teachers should specifically prompt them to address problems relevant to their cultures, ethnic backgrounds, genders, or other personal contexts (e.g., designing a smart, shared digital frame and hub to connect community members). During the presentation of their device or solution, students should be asked to articulate its relevance to their community, thereby demonstrating how technology can be developed in diverse ways when different perspectives are applied. This approach emphasizes the critical need for diverse engineering teams to ensure that technological solutions address the specific needs of a broad range of populations.

Inquiry - Shine Smart, Shine Bright

UDL Checklist Application	Teachers should consider positioning Step 1 as an application phase, to be conducted at the end of the protocol. As urban lighting may be an unfamiliar topic for students, it would be more beneficial for them to begin with concrete and straightforward tasks, such as observing the lighting in their residential streets, commercial areas, or shopping malls. Key parameters for observation should be defined, including light intensity, color, and operational hours. Furthermore, discussions should explore the characteristics of effective lighting from various perspectives, encompassing social aspects, ecological and biological impacts, physics principles, and energy conservation. Following this observation phase, students can then formulate general guidelines in a structured manner and compare these guidelines with case studies from other cities globally (original Step 1). This comparative analysis can also be valuable for refining the recommendations they provide to city councils or mall managers in Step 3.
Stereotype Challenging Opportunities	Teachers should engage students in imagining the profiles of professionals involved in city planning, specifically concerning urban lighting. Emphasis should be placed on the necessity of interdisciplinary teams, highlighting that engineers design efficient solutions, city planners focus on secure urban environments, and biologists contribute by mitigating the impact of lighting on urban ecosystems (e.g., light attraction of insects affecting pollinators, disorientation of migratory birds, altered foraging patterns in nocturnal mammals, or physiological effects on human health).
Other aspects regarding the promotion of social justice in STEAM	Teachers should revise the observation form and urban lighting perception questionnaires with students beforehand to ensure all questions are relevant to their contexts and to identify any questions that should be removed or added.

Inquiry - SoundSquad. Sensitive mapping of noises

UDL Checklist Application	This protocol relates to the “Light vs. Zzz” protocol and could serve as a precursor. Teachers should consider applying sensitive mapping and quantitative analysis of sound to specific groups of students with special needs, such as those on the autism spectrum, leveraging their firsthand experiences to develop the sensitive mapping, given their heightened sensitivity to sounds.
Stereotype Challenging Opportunities	Teachers should consider developing sensitive maps tailored to specific needs, such as for parents with infants or individuals with migraines who require quiet spaces for shopping or other activities. Emphasizing the connection between technology and improving these individuals’ living conditions can challenge common stereotypes about STEM being purely academic or abstract.
Other aspects regarding the promotion of social justice in STEAM	Discussions should explore how soundscapes vary across different urban areas, particularly between wealthier and less affluent neighborhoods, and the implications of these differences for environmental justice and the disproportionate impact of noise pollution on certain communities.

Inquiry - Whisper Walls. Investigating the Sound of Silence

UDL Checklist Application	This protocol can be integrated with the “Light vs. Zzz” protocol as an application phase. To facilitate student understanding of how different materials attenuate sound, it is advisable to use a (digital) magnifier to illustrate material composition. This can clarify how porous materials absorb sound while dense, hard materials reflect and block its transmission, explaining the resulting acoustic sensations. Furthermore, providing visual representations of sound waves can offer complementary inputs, aiding students in developing their interpretations of the phenomena.
Stereotype Challenging Opportunities	Teachers should strive to provide a clear purpose for conducting experiments on sound attenuation, allowing students to identify a need for their research. While the protocol suggests exploring noise-barrier innovations in cities, a more domestic and personally meaningful challenge (e.g., building a rehearsal space for musical activities, designing passive noise-canceling materials for headphones) can emphasize the connection between STEM and students’ daily lives, challenging the stereotype that STEM is solely about large-scale, impersonal projects.
Other aspects regarding the promotion of social justice in STEAM	Teachers should integrate students’ everyday sound experiences into the discussion. For instance, before an experiment, students could anonymously report sounds heard from their rooms and their impact on well-being, acknowledging that some students may live in challenging conditions. This highlights that noise pollution extends beyond city noises to include building materials and lifestyle factors. This information can be used in initial discussions or a final stage where students select materials to attenuate specific noises.

Inquiry - Trees vs. Cars. Identifying Polluting Vehicles

UDL Checklist Application	While scaffolding is provided for developing decision trees, teachers should consider initiating the activity with a simpler, more accessible application, such as “How to choose what to wear.” As building a decision tree is an abstract concept, simplifying the initial decision-making process can reduce cognitive load, lowering the entry barrier and allowing students to focus on the underlying logic of decision trees.
Stereotype Challenging Opportunities	Discussions with students should extend beyond identifying permitted and non-permitted cars in low-emission zones to explore the broader applications of decision trees. Connections should be made from simple applications (e.g., winning in “Who Is It?”) to complex ones (e.g., dichotomous keys in biology, diagnosis support systems in healthcare, quality control in manufacturing). An application activity could involve comparing the similarities and differences of decision trees across diverse applications to enhance student understanding of factors contributing to tree efficiency, thereby broadening their perception of STEM applications beyond vehicles.
Other aspects regarding the promotion of social justice in STEAM	Given that the protocol is developed around the case of Brussels, teachers should consider necessary adaptations to align it with the students’ own city or town. This customization can significantly enhance student engagement by making the learning experience more relevant and relatable to their local context.

Inquiry - Waste Sorting Thanks to AI

UDL Checklist Application	As students may not be AI programming experts, it is advisable to provide graphical examples illustrating what to observe in Step 3 (analyzing interactions between neurons in the neural network). A clear purpose for this analysis should be given, such as identifying incorrect connections after the AI misidentifies an image.
Stereotype Challenging Opportunities	Teachers should facilitate discussions with students about the real-world individuals behind AI innovations. Students should be encouraged to express their perceptions of these professionals and connect their attributes to their own experiences (as they have also acted as data science professionals). This helps demystify these roles and demonstrates the diversity of individuals within STEM professions.
Other aspects regarding the promotion of social justice in STEAM	Discussions should address biases in image identification resulting from inappropriate supervised training. Teachers can initiate this by examining well-known cases, such as the disproportionately higher misclassification rates for dark-skinned faces or instances of misgendering due to AI systems predominantly trained on binary gender classification. This fosters critical thinking about ethical AI and social equity.

À PROPOS DE L'AUTEUR

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