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Adapting the Gender Based Analysis Plus (GBA+) to Engineering: A Digital Tool to Aid Inclusive Design

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Pre Nathalie Roy obtained her PhD in 2006 and she is professor in the Department of Building and Civil Engineering at the Université de Sherbrooke since 2009. She has been the Faculty advisor of the Canadian Society for Civil Engineering (CSCE) student chapter from 2009 to 2020. She is currently Deputy co-chair of the Engineering Mechanics and Material Division and a member of the regional committee – Quebec. It was a great honor for her to chair the Technical Program Committee of the CSCE annual conference held in Laval, Quebec in June 2019. In 2021, she was appointed Vice-Dean of undergraduate studies and for Equity, Diversity, and Inclusion (EDI) of the Faculty of Engineering, Université de Sherbrooke. Beside her many contributions related to EDI and her involvements in various student's projects, she is still quite involved in research. Her main fields of research interest are structural dynamics and earthquake, along with large-scale testing of structural elements. She is an active member of several research groups and associations. Professor Roy is committed to and supports the involvement of students in international cooperation projects. Seeing the importance of helping disadvantaged communities through the knowledge acquired during engineering programs, Dr Roy became a member of the Université de Sherbrooke International Collaborative Group (GCIUS) which is a student non-profit organization. Since 2002, the group has been working on high impact civil engineering sustainability projects in developing countries. Nathalie was quite involved in the projects and went on site with the students in Malawi (2014), Nepal (2016), Tanzania (2017), Ghana (2018), Benin (2019-2022), Ouganda and Côte d'Ivoire (2023).

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Introduction

The main objective of this project is to develop a new pedagogical approach composed of two complementary components aiming at integrating equity, diversity, and inclusion (EDI) into undergrad engineering programs at Université de Sherbrooke (UdeS) (Canada): (1) a training program and (2) a numerical tool for inclusive design. The training program will comprise two modules. The first one will be for design instructors so they can develop the skills to teach these abilities in class and learn how to use of the tool. The second module will be for undergraduate students to develop their ability to integrate EDI into design projects.

This paper focuses on the progress of the development of the digital tool for inclusive design. Mainly, the content of the tool will be presented. This pedagogical innovation approach aims at developing an engineering-adapted version of Genger Based Analysis Plus (GBA+) to support engineering students to improve the design process by considering the impact on diverse groups of people.

To begin, the pedagogical and innovative context in which this tool is currently designed and how it will be developed will be discussed. Although this paper mainly describes the development of the tool, the training program will be briefly discussed. Furthermore, the progress of tool content development will be detailed by presenting the steps reached so far in *phase 1: analysis* and in *phase 2: development of the tool*. Along challenges and success factors will be discussed. Finally, a preliminary version of the tool content and framework will be presented.

Context

GBA+ is a globally recognized tool that has been implemented by the Canadian government since 1996 [1]. Nowadays, this approach is implemented across federal departments and agencies to ensure that policies, programs, legislation, and other initiatives are sensitive to diversity factors of Canadian population groups. GBA+ is a cross-cutting and intersectional analytical tool that assesses systemic inequalities and determines the potential impacts of policies, programs, and initiatives on various population groups.

In addition to gender and sex, GBA+ examines “many other identity factors such as race, ethnic origin, religion, age, and physical or mental disabilities, and how their interaction influences how we may experience government policies and initiatives” [2]. GBA+ thus aligns with a context of evolving social norms, the fight against inequalities, and the adoption of measures that reflect the diversity of experiences and the values of EDI. This intersectional lens acknowledges that individuals have different identities that influence their experiences differently [3].

Intersectionality being at its core, this tool provides a broader understanding of specific needs and allows decision-makers to address them through adapted solutions.

Therefore, GBA+ enables the development of more rigorous community-centred solutions to address EDI. Accordingly, this analytical tool can be applied in other contexts such as engineering design process which emphasizes on open-ended problem solving to create innovative solutions to challenges in any subjects impacting society.

Nowadays, the Faculty of Engineering at the Université de Sherbrooke (UdeS), Canada, aims to integrate EDI concepts into its undergraduate program curricula. This objective aligns with the intention of the Canadian engineering accreditation board (CEAB) to integrate EDI through accreditation requirements for engineering programs in Canada.

CEAB, an instance related to Engineers Canada, regulates engineering education in Canada and is responsible for accrediting undergraduate engineering programs. Program accreditation is required to issue permits for professional regulatory bodies in each province of Canada. In the United States of America (USA), engineering programs are under the supervision of an equivalent organization, named the accreditation board for engineering and technology (ABET). To standardize engineering practices and create equivalences across different countries, agreements exist between the different accreditation boards. Due to their proximity, a specific agreement exists between Canada and the USA [4], yet other ones were established with other countries for the same purpose. Thus, accreditation boards are highly influenced by one another and changes on one side can inspire great improvements in the profession worldwide.

In 2014, CEAB reviewed its accreditation process to align their requirements to those implemented by ABET by adding a list of 12 attributes that graduates must develop during their training in conjunction to the continuous improvement of programs. The attributes address technical skills as well as social, ethical, and organizational skills within engineering practice to respond to the globalized and diversified environments that engineers will need to evolve in [5].

Diversity is omnipresent in engineering regarding the sectors where engineers can work, the problems they can solve, the multiple solutions they can propose, and the variety of people involved. As demonstrated in many papers [6], diversity in engineering is of great importance to create different approaches to problem-solving and better service for everyone.

The provincial Quebec's professional order of engineers defines the profession as "solving concrete and often complex technical or technological problems related to the design, realization, and implementation of infrastructure, products, systems or services" [7]. Yet, the organization mentions the difficulty of defining an engineer's role since engineering is practised in a wide variety of sectors such as construction, energy, mechanics, robotics, biotechnology, chemical and much more. Furthermore, even though an engineer is trained in a specific field, it does not necessarily restrict the profession to a specific sector. For example, an engineer from a mechanical engineering background can work just as much in the design and production of cars than in a chemical industry. Therefore, depending on the sector and the size of a project, an engineer is confronted to very different challenges regarding the designs they must conceive and the people they must interact with. Additionally, engineers are often brought to work with people from different nationalities since many projects require international collaborations. The nature of the profession brings engineers to work in interdisciplinary and multicultural environments.

To encourage diversity, engineering programs are creating flexible pathways and promoting engineering to the unusual demographic populations [8]. However, changes in engineering can not only come from changing the recruitment strategies, the content of the courses must also change. EDI must be addressed within the programs to increase the student's awareness to the difference in treatment an engineering design can cause [8].

Consequently, it is appropriate to link new pedagogical strategies to specific attributes that engineering graduates must develop in Canada. Among these 12 attributes, two of them are specifically impacted by EDI concepts: Attribute 04 (A04 - design, which involves designing solutions to complex and evolving engineering problems while considering economic, environmental, cultural, and social aspects) and Attribute 09 (A09 - engineering's impact on society and the environment, which involves analyzing the potential social and environmental impacts of their designs on gender equality and other diversity factors, e.g., disabilities, visible minorities, language, etc.). These attributes are akin to competencies. Therefore, all future engineers must develop solutions to complex engineering problems (A04 - design) while considering differentiated social impacts based on gender, gender identity, and other identity factors during the design of an engineering product or process (A09 - engineering's impact).

The following example demonstrates the application of GBA+ in a capstone student project. This project focuses on the design of a robotic arm intended for quadriplegic individuals. In this example, GBA+ allows for the consideration of various identity factors to design a robotic arm adapted to the diverse realities of quadriplegic individuals. First and foremost, the factor of disability is central to the development of this technology, as it is intended to be used by quadriplegic individuals. Therefore, it involves considering the loss, to varying degrees, of muscle functions and sensations in the affected limbs. This can manifest as the analysis of various variables such as the degree of mobility loss. Furthermore, an intersectional analysis is relevant to incorporate variables such as gender and age, for example. Muscle function varies according to both factors [9] and considering them during the design allows to ensure that the robotic arm is adapted to the population.

Unfortunately, there are very few concrete tools conveying the concepts of EDI adapted to the context of engineering practice. Currently, these concepts are not explicitly taught in engineering programs at UdeS and not systematically in other engineering programs in Canada (see subsection PHASE 1: Analysis). In that sense, GBA+ remains an unfamiliar tool to engineering educators and has not yet been adapted for use in university engineering education in Canada.

Currently, the material that will be included in the digital tool is at the development stage. A team has been successfully formed for the pilot phase of the project by engaging 4 out of 8 study programs (civil, building, mechanical, and robotics), as well as the coordination of major capstone design projects regrouping 4 of our study programs (robotics, electrical, computer science, and mechanical) to participate. The major capstone design projects are a series of mandatory interdisciplinary pedagogical activities. These major capstone projects span the last three sessions of the bachelor's degree, equivalent to a period of 20 months. An interdisciplinary student team is formed to create a project from its initial idea to its design. These projects provide an advanced and realistic context for engineering practice as they allow students to apply all the skills they have learned during their studies.

Pedagogical innovation approach

In this project, the pedagogical innovation approach consists of two complementary components: (1) developing a digital tool to inclusive design in engineering and (2) developing a training program, consisting of two modules designed to enable the use of the tool in a pedagogical context.

<u>Developing the training program and the digital tool to aid inclusive design</u>

The core of our approach consists in developing a digital tool to aid inclusive design in engineering by adapting GBA+ to the engineering design process based on engineering scenarios in a pedagogical context by all future engineers. It aims at integrating the EDI concepts into the training curricula of undergraduate students by learning how to measure the impact of a design project on gender and other population groups. This approach promotes integration of social justice into curricular activities. It also encourages the development of professional behavior and responsible citizenship and enriches the development of skills in design and in analyzing the impact of engineering on society and the environment.

<u>Developing the training program</u>

Two modules will be developed following the Bloom's Taxonomy and in accordance with the learning path of undergraduate engineering students (see Figure 1) as well as the design instructors' (see Figure 2). These modules aim at training them to learn EDI concepts and its application on the design process by using the tool for inclusive design.

Module 1: Common Core in Asynchronous Mode will be developed for design instructors and undergraduate engineering students. Its main objective is to familiarize them with EDI concepts into design process and learn how to use the tool in a pedagogical context. Following Bloom's Taxonomy steps one to four, four subobjectives are targeted (1) understand the basic concepts of GBA+ and its application to the design process, (2) understand its main ideas, (3) apply knowledge to a practical case, and (4) analyze a complex engineering problem by applying the tool for inclusive design.

Figure 1 – Learning Path for Undergraduate Engineering Students

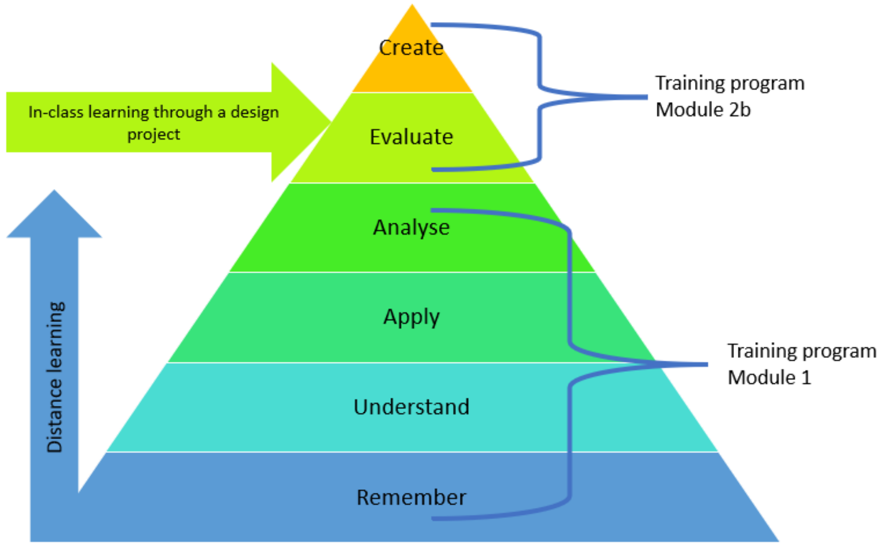
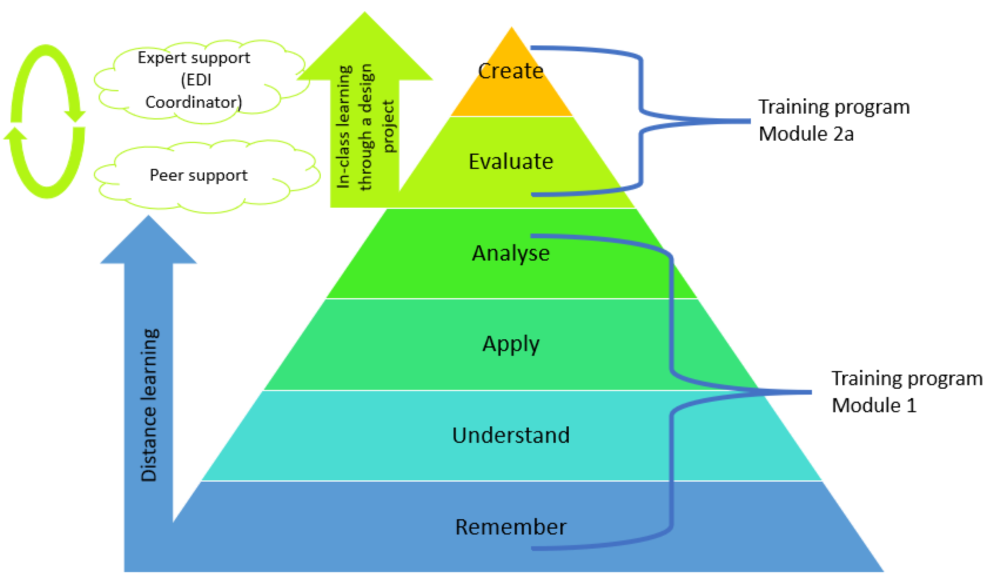


Figure 2 – Learning Path for Design Instructors



Module 2a: Complementary Module in Hybrid Mode will be developed for design instructors having the objective to support their autonomy to use the tool for inclusive design in a pedagogical context and their ability to act as a facilitator to guide students in applying and integrating their knowledge learned in Module 1 into a design project [10].

Module 2b: Complementary Module in Flipped Classroom Mode will be designed specifically for undergraduate engineering students. Its main objective is to train the students to be able to apply and integrate their knowledge learned in Module 1 into a design project using the flipped classroom model to promote engagement and active learning [11].

Following Bloom's Taxonomy steps five and six, two subobjectives are targeted for Module 2, (1) design a solution to a complex engineering problem by applying GBA+ concepts and (2) assess and support students in applying GBA+ concepts in a design project.

Progress of tool content development

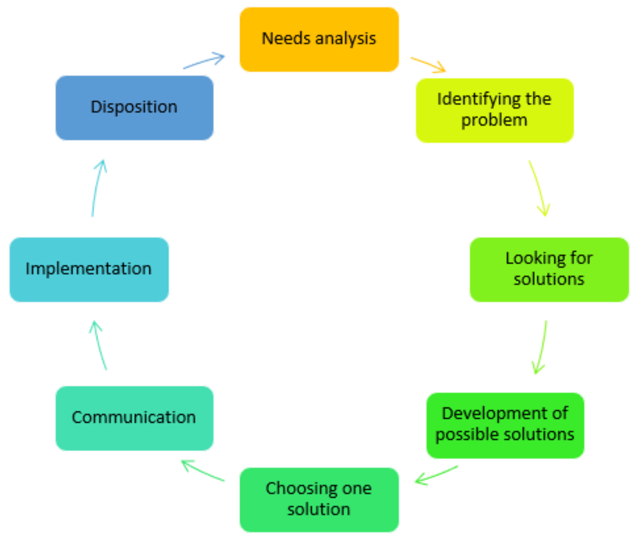
PHASE 1: Analysis

This phase comprises the five following steps: 1) Documenting GBA+ and its potential application to engineering design process, 2) Identifying existing EDI training courses in Canadian engineering programs, 3) Determining the project's pedagogical alignment, 4) Consolidating the literature review on engineering design process and EDI, and, finally, 5) Identifying training needs through consultation. These steps are leading to develop the content tool content and framework.

STEP 1: Documenting GBA+ and its potential application to engineering design process

Inspiring tools and guides have been developed by governmental and higher education institutions. Stanford University has developed *Gendered Innovations* [12] which propose specific methods to encounter gendered bias by analyzing gender and intersectionality in designing. Through these methods, we come to understand the importance of considering the impact of these factors in the development of such technologies and its feasibility. The Ministère des transports of Quebec has developed the *Guide d'analyse du genre adapté au domaine des transports* [13] which present a Quebecois version of GBA+ applied to transportation domain while illustrating it with concrete examples. GenderMag [14] is also an inspiring source since it proposes a systemic method for identifying and eliminating gender barriers in technological design. These three sources have helped the team developing the content of the tool to aid inclusive design. GBA+ precisely improves existing methodologies [2] and the design process where applicable, as it enriches problem analysis in a more rigorous, equitable, diverse, and inclusive manner. The application of GBA+ concepts allows for process improvement as it ensures the adaptability of a design to a wider population. For example, a study [15] shows that some facial recognition algorithms have a high error rate of 24% against dark-skinned female faces compared to light-skinned male faces. Conducting a gender and skin color differentiated analysis would help anticipate such impacts and develop less discriminatory algorithms towards certain categories of individuals. This example demonstrates the relevance of adopting GBA+ to the engineering design process to integrate EDI concepts into student education and skills development. The relevance of adapting GBA+ to engineering design process shown in Figure 3 is well documented (see step 4).

Figure 3 – GBA+ in formal design process



GBA+ should be considered at all stages of the formal design process to assess possible impacts on gender, sex, and other diversity factors (from needs analysis to the final implementation of the selected solution).

STEP 2: Identifying existing EDI training courses in Canadian engineering programs

The literature demonstrates that the engineering community in Canada aims at integrating EDI concepts into higher education. Two aspects were studied: (1) EDI commitment in organizational culture and, (2) embedment of EDI into education curriculum.

<u>(1) EDI commitment in organizational culture.</u> The literature review shows the commitment of Canadian engineering faculties to develop a more inclusive, diverse, and equitable organizational culture. Two general trends can be observed.

Firstly, some faculties (e.g., Faculty of Engineering at the University of Sherbrooke [16], Faculty of Applied Sciences at the University of British Columbia [17], Faculty of Applied Science and Engineering of Toronto University [18], and Faculty of Engineering at Alberta University [19]) state their commitment to EDI within their strategic plans as a broader and transversal vision. They sometimes integrate specific objectives in this regard. These objectives generally pertain to recruitment practices and the development of an inclusive culture through community awareness on EDI.

Secondly, other faculties have adopted specific EDI policies and action plans covering recruitment practices, community awareness of EDI issues, improvement of the student experience, communication strategies, and fundraising to support initiatives. For example, the Faculty of Engineering at McGill University has identified EDI priorities [20] – Recruitment

Life Cycle, Faculty and Staff EDI Education, Student Experience, EDI Advocacy Program, Communication and Engagement Strategy, Resources and Funding Strategy that will guide their units to develop their own unit-specific EDI strategy. Polytechnique Montréal has also adopted an EDI policy [21] named *Politique en matière d'équité, de diversité et d'inclusion*, establishing guiding concepts and an EDI governance structure. Similarly, some faculties have hired specific resources related to EDI (e.g., UdeS), while others have also established EDI committees to support the implementation of action plans (e.g., McGill and Polytechnique Montréal).

The embedment of EDI into curriculum programs doesn't seem to be part of any strategic plans nor specific EDI policy or action plans of Canadian engineering faculties. This commitment is crucial but does not stand on its own. Since engineering faculties are aiming for a culture shift, this requires structural and cultural changes at many levels including a culture shift into curricula of future engineers. In that sense, higher education institutions need "to examine what [they] are teaching and how [they] are teaching it" [8]. This leads to the second observation.

<u>(2) Embedment of EDI into education curriculum.</u> EDI does not seem to be embedded in the academic curriculum in study programs. Currently, EDI training are offered with the aim of raising awareness within the academic community, but outside of regular courses and on an optional basis. This observation reflects the criticism stated by Jacobs, "[one] problem with most [EDI] programs in higher education is a focus on internal issues and a minimal focus on the curriculum." [22]. This requires a reexamination of the teaching and methods taught in engineering, as they themselves constitute a biased system that can have maintained inequalities. Three ways to embedded EDI in the academic engineering curriculum have been identified.

Firstly, some strategies are aiming at developing EDI components to teaching strategy with the objective to enhance students' educational experience. For example, the Teamwork Program at McGill Engineering Faculty [23] aim to partner "with instructors in the Faculty of Engineering to develop specialized workshops aimed at teaching teamwork skills and building applicable knowledge around [EDI]. [Their] approach supports instructors in reimagining their pedagogy to improve student teams' abilities to work together in more effective, equitable, and engaging ways."

Secondly, some strategies intend to develop soft skills related to EDI such as communication, leadership and teamwork that enhance students' ability to interact in a diverse work context. For example, "the OPSIDIAN training program [24] provides trainees with the Power Skills needed to integrate interdisciplinarity and diversity for creative sciences and engineering research teams. Power skills include diversity- and interdisciplinary-driven communication, teamwork, and leadership''.

Thirdly, some strategies are integrating EDI into students' education in a more structural way. For example, EDI have been integrated into a cornerstone design course in Mechanical and Industrial Engineering at Ryerson University to ensure that students can understand a wide range of users' needs regarding human capabilities and limitations [25]. Various human factors (HF) are considered such as vision, hearing, and strength. An important challenge has been reported regarding the difficulty "to provide sufficiently comprehension yet accessible HF tools to handle all aspects of a product's design for an introductory design course" [25]. This project is inspiring and shows the feasibility of integration EDI into design course.

STEP 3: Determining the project's pedagogical alignment

All the design courses offered in the 8 study programs (civil, building, electrical, computer science, robotics, mechanical, chemical, and biotechnological) at UdeS were reviewed. To cover the different stages in students' educational paths, courses were identified at the beginning (year 1 and 2) and end of the undergrad studies (year 4) and targeted 4 study programs. Specifically, 3 professors and instructors responsible for design courses in 4 UdeS study programs (civil, building, mechanical, and robotics) have been identified. These individuals are more involved in the early stages of undergraduate studies. Also, courses related to the completion of major capstone design projects that occur at the end of the undergraduate program have been selected. These major capstone design projects aim to apply all the skills acquired during the undergraduate program including attribute A04 (design) and attribute A09 (engineering's impact). The coordinator of these mandatory pedagogical activities is involved with 4 of our study programs (robotics, electrical, computer science, and mechanical). This sampling allows us to create a test group that will be involved into the designing phase of the training program and the digital tool and the development of specific study cases related to these 4 engineering fields.

STEP 4: Consolidating the literature review on engineering design process and EDI

While consolidating the state of the art, the following question served as a guide: "Is there engineering systems that are not suitable or adapted to a portion of the population?" To do so, specific categories of factors were studied (1) sex and gender, (2) age, (3) body factors, (4) disabilities, (5) language and voice, and (6) skin color. Intersectionality was at the heart of our approach to analyze differential impact considering the interaction of gender or sex with other diversity factors (e.g., sex and skin color, sex and height, sex and safety, etc.).The main objective was to show the relevance of considering the impact of interaction between many factors in designing to reduce inequity.

<u>(1) Sex and gender.</u> Since GBA+ is initially focused on assessing the impact of initiatives based on gender and sex, this part of the literature review identifies engineering designs that have different impacts according to these factors.

As a first step, it is important to clarify the difference between sex and gender because they are often used interchangeably despite having different meanings. *Sex* describes a set of biological, physiological, and physical characteristics such as chromosomes, hormones, and genital organs [26]. Depending on these characteristics, an individual is attributed at birth to one of the two categories: female or male [26]. On the opposite, *gender* is a social construction where different roles, behaviors, expressions and identities and behaviors are expected from society for women, men and diverse people [27]. "It influences how people perceive themselves and each, how they act and interact, and the distribution of power and resources in society" [26]. Being not static nor dichotomous, gender is a continuum that constantly evolves. Gender also refers to the diversity "in how individuals and groups understand, experience and express gender through the roles they take on, the expectations placed on them, relations with others and the complex ways that gender is institutionalized in society." The following examples present some cases where inequalities appear in engineering systems due to differences in sex and/or gender depending on the case study.

Firstly, all engineering designs are impacted by the choice of materials used. Biological and physiological differences between females and males (sex) impact how our bodies react, and this is observable once confronted to different substances and materials. For example, it has been shown that the health effects of toxic metals differ for females and males [28]. Research highlighted that males seem to be more affected by skin problems due to arsenic than women. Arsenic is primarily used in the electronics industry to make semiconductors, LEDs, and solar cells [29]. The choice of materials used in designing various products is important and having data for a material on only one sex does not prove it is safe or has the same impact on the entire population. Since all engineering designs require the use of materials to create a final product, each engineering program is impacted by this question. However, the quantity of materials used and how much time humans are in contact with these components vary. All these characteristics must be considered to be able to evaluate the impact of an engineering design on society. In addition to assessing the impact of materials used in the design of equipment, chemical and biotechnological engineers must also verify the impact of the substances manufactured through the designed processes. Indeed, the substances produced by a chemical or biotechnological process will not necessarily have the same impact on both sexes depending on its quality and properties. For example, differences in drug response for both sexes appear for many products [30]. When designing a process, it is worthwhile to wonder who's need will this product answer to, and if there should be different specifications for different sexes.

Secondly, engineers are also involved in creating the environment people navigate in such as buildings (heating, lighting) or the public space. Depending on sex and gender, the experiences one faces can vary.

Have you ever noticed that women tend to be cold at work? Parkinson et al. [31] demonstrated that office temperatures are less comfortable for women in the US largely due to overcooling, regardless of the season. Overcooling has been attributed to poorly designed or managed air-conditioning systems with thermostats that are often set below recommended comfort temperatures. Additionally, these recommended temperatures are based on a model using the metabolic rate of an average male [32], and therefore overestimating female metabolic rates by up to 35%. These conditions make buildings non-energy-efficient in providing comfort to females. The design of a building, as well as the heating and cooling systems depend on the standard operating range required and not considering the differentiated needs associated with sex creates inequalities. Furthermore, energy consumption of residential buildings and offices add up to about 30% of total carbon dioxide emissions and occupant behavior contribute to 80% of the variation in energy consumption [33]. Considering accurate thermal demands allows designing buildings adapted to the entire population leading to less variability and as a result energy savings. Using gendered data will help civil and building engineers design more efficient and equitable spaces.

In addition to differentiated heating needs per sex, studies [34-36] have also shown preferences in lighting. Quality of lighting can be defined by illuminance and color temperature. These settings can either support activation to improve productivity or relaxation to facilitate recreation. Mc Cloughan et al. [36] presented results showing that females preferred warm lighting and high illuminance levels whereas males' negative mood tended to increase with higher illuminance. On the other hand, males did not show any significative preference for a warm or white light source. Considering the contribution of lighting on mood and human performance [34, 35], it is necessary to consider the quality of light based on data for both sexes to create adapted environments. Even if the choice of lighting in buildings might not be part of an engineer's role, electrical engineers are involved in the design and production of lighting systems and acknowledging the different needs of the population influences what is available on the market.

Thirdly, biological characteristics may also be considered in the design process. On one hand, it still is common for male to pee while standing. In contrast, the impact of menstrual cycles is undeniable on female bathroom habits. But were these differences considered while designing public bathrooms? As questioned by Anthony and Dufresne [37]: "How many times have you been trapped in long lines at the women's restroom? Why must women be forced to wait uncomfortably to relieve themselves, while men are not? ". Although it might not be directly an engineer's responsibility to determine how many toilets to incorporate in each bathroom, these decisions impact plumbing and the design of the system. An obvious alternative to reduce these inequalities is to create non-gendered bathrooms. In addition to creating equal accessibility, non-gendered bathrooms can offer greater safety since school toilets have been identified as the least safe spaces in educational institutions for sexuality and gender diverse students [38]. Non-gendered bathrooms also allow a better access to parents when accompanying their children of the opposite sex to the bathroom [37]. Furthermore, the location of bathrooms in public spaces is also determinant to accessibility. A sex and gender analysis are necessary to highlight these differentiated experiences and needs, which will in terms allow civil and building engineers design more inclusive spaces.

Fourthly, the conception of electric devices that enable the usage of apps and software have gendered impacts. A research team identified that the way people use software often cluster by gender and especially regarding problem-solving [14,39]. Their research highlighted that many software features are inadvertently designed for people who have problem-solving styles generally attributed to men. This led to the development of a tool called "GenderMag" [14] to help software developers create features better suited to other styles of problem-solving and ultimately, a more intuitive software for everyone. The use of this tool is pertinent in computer science and robotics.

(2) Age. The factor of age is also relevant when designing a product since it influences other factors such as strength and height. Strength varies with age, and loss of mobility has repercussions on our day-to-day life such as opening doors or taps in bathrooms. In 2014, a law was adopted in British Columbia to ban round handles as they were very hard to turn for people with arthritis [40]. Moreover, whether a product is designed for children or adults requires different features. The *UX Design for Children* [41] presents guidelines to create web and apps

adapted to their needs. A recent study even shows their physical abilities related to age such as tapping or scrolling to be considered during design [42]. These examples illustrate that the age of a person influences their capacity to use a system, whether it is operated mechanically or virtually. As a result, the influence of age is relevant in all engineering designs.

<u>(3) Body factors.</u> When searching to buy a car, internet forums discuss which cars are better suited for tall [43] or short persons [44]. This does prove that when designing a car mechanical engineers make decisions that favor or exclude certain people. Yet, a person's body factors are also influenced by their sex and each factor can not be treated independently. The following example illustrates that a problem is never unidimensional. Furthermore, this example brings up another question, when is it appropriate to use an average, or is it more appropriate to use extremes.

During the manufacture of cars in the US, the question of height seemed to be the main factor that was considered initially to check the safety of car designs. The first crash test dummy created was based on an average American man in the 1970s (1976), and several years later a scaled down version of that dummy was created based on the smallest 5% of American women in the 1970s (1988) and a scaled-up version of the initial dummy based on the tallest 95% of American men from that same period [45]. Even though, the size of a person is a determinant in a car crash, these dummies did not consider female's specificities such as differences in the shape of the torso, hips, pelvis and different muscle strengths. A Swedish team has recently proposed a dummy that represents a female body [46].

In the same way as age, different body factors determine how a person uses a system. If an engineering design requires human interaction, considering the variety of existing body factors is necessary to guarantee it is safe and ergonomic for all.

<u>(4) Disabilities.</u> Different senses, such as hearing, sight and touch can also make designs inadequate for a portion of the population. The web content accessibility guidelines [47] created international recommendations to make the internet more accessible and primarily for people with disabilities. Improving systems while considering people with disabilities can improve them for many users just like it was the case when adapting sidewalks for disabled persons [48]. The implementation of curb cuts (sidewalk ramps) benefitted everybody: parents pushing strollers, workers pushing heavy carts, business travellers wheeling luggage, even runners and skateboarders. Angela Glover Blackwell [48] named this phenomenon "The Curb-Cut Effect" and describes how addressing disadvantages or exclusions experienced by one group of people creates an environment that enables everyone to participate and contribute fully. Therefore, all designs that require human use and interaction would benefit from checking if it is appropriate for someone with a disability.

Nowadays, there is in an increase of people suffering of allergic reactions [49] and this can be problematic when products contain traces of contaminants due to cross contamination. Considering how equipment or a process must be cleaned when designing, it can help to improve to cleaning procedures and manufacturing products safer for everyone. Chemical and biotechnological engineers must pay attention to the process flow of a substance to determine potential contaminants and how to prepare equipment before production (cleaning). Yet, mechanical engineers also have a part to play when designing equipment to avoid inaccessible residues.

(5) Language and voice. Many technologies based on artificial intelligence (AI) have been developed to facilitate daily tasks such as AI bots and voice assistants. Yet, these tools can perpetuate inequalities depending on how it is designed. Historically, gendered-related stereotypes have shaped normative expectations for women and for men which means that women are more expected to act as a supporting roles because they are considered as submissive and compliant. Studies have shown that these stereotypes are reinforced by AI voice assistants. For example, the predominance of female voices (either as the default or the only option) reinforces gender stereotypes such as an assistant should, by default, be female [50,51].

Moreover, algorithms do not always acknowledge user gender (including non-binary) or understand context-bound and culture-bound language [52]. This can lead AI bots to misread a situation and not to respond properly to a simple question. In that sense, a study [53] shows that when questions are asked to Siri, Google Now, Cortana, and S Voice about mental health, interpersonal violence, and physical health, they provided inconstant and incomplete answers. Another study demonstrates that “feminized digital voice assistants have often been programmed to respond to harassment with flirty, apologetic and deflecting answers” which reinforce the preconceived notion that women will not fight back harassment [54]. AI voice assistants can also provoke bias in audio interaction depending on gender and accent of the speaker which leads to the exclusion of certain groups of people [55]. According to Lima & al. [55], Google and Siri seem to recognize female voices more readily in transcription processes. These algorithms also better recognize certain accents from English speakers, enabling improved transcription based on the speaker's accent. The lack of voice variety in databases can cause voice recognition efficiency.

Engineering systems that rely on the use of voice are advanced technologies; therefore these characteristics are mainly to be considered in computer science and robotics.

(6) Skin color. Skin color is also a factor that needs to be considered in designing because it contributes to perpetuating racial inequities and discrimination. Studies [15,56] demonstrate that algorithms have lower matching accuracies on black people which leads to discriminatory behaviors. For example, Bacchini and Lorruso (2019) [56] expose “that black people are overrepresented in many of databases” and consequently, “[they] are more often stopped, investigated, arrested, incarcerated and sentenced”. The Gender Shade project [15] also confirms such observation by adding an intersectional lens. That study shows that algorithms consistently demonstrated the poorest recognition accuracy for female faces (vs. male) and worst for darker-skinned females. This can be explained by the facts that codes are trained to focus on white faces, algorithms are mostly tested on white subjects and databases are mostly composed of white faces.

Hence, computer science and robotics are concerned by skin color, but other engineering programs should also check that the designed product satisfies the needs of all skin shades.

Finding adapted products for darker skin colors was and, in some cases, still is a struggle today. To mention a few examples, this is a case for make-up products (chemical and biotechnological engineering), plasters [57] and ballet shoes [58] (mechanical engineers if required to identify materials with different properties or chemical and biotechnological engineers to develop new manufacturing processes).

STEP 5: Identifying training needs through consultation

Since November 2023 and until March 2024, the team will be conducting consultations to help identify training needs for design instructors (so that they are well prepared to use the tool in a pedagogical context) and for students (to support their learning in class).

The team is currently (November 2023 to January 2024) meeting with the project team members to identify their needs and those of the students to ensure they align with the achievement of attributes A04 and A09 and identify design projects as examples to apply GBA+ related to each engineering field that will be integrated into training modules.

Meeting with people from different departments allowed to understand their specific design challenges and where differences in experience could arise. It was mentioned that it can be difficult to identify scenarios where inequalities appear at the begin, but examples help to adopt the way of thinking of questioning the design process. These discussions allowed to fine-tune the examples presented in this paper and the engineer's role in these situations.

After consulting team members, we aim at consulting students through focus groups (February 2024) to identify the most suitable learning methods tailored to their realities, to assist us in (1) developing the training modules for students, and (2) pinpointing the best digital method for creating the inclusive design support tool.

<u>PHASE 2: Development of the tool</u>

STEP 1: Designing a preliminary version of the inclusive design support tool

The team is currently at the stage of designing a preliminary version of the tool. As a first step, the content has been determined by pinpointing key questions onEDI aspects that need to be considered for each designing steps. Regarding the framework of the tool, the team has been allowed to adapt a grid on governmental department pathway integration for ADS+ [13], which is the Quebecois version of GBA+, developed by the Ministère des transports of Quebec.

The following table presents a preliminary version of the tool indicating the different steps and questions to include. These steps coincide with those of the design process identified in figure 3.

This draft will be reviewed by design instructors and professors. Finally, this tool will be in digital form. The final format (e.g., application, web page, interactive Genially, etc.) used will be determined based on the training and usage needs of students. This will be evaluated in the winter of 2024 following student focus groups.

Table 1: Tool for inclusive design

PROJECT DEVELOPMENT

STEP 1: SELF-EVALUATION OF THE DESIGN ENVIRONMENT

Before starting any design process, it is important to self-evaluate the design environment to prevent the most possible the impact of our unconscious bias on design.

What is an unconscious bias? It is "an implicit attitude, stereotype, motivation or assumption that can occur without one's knowledge, control or intention. Unconscious bias is a result of one's life experiences and affects all types of people. Everyone carries implicit or unconscious biases. Examples of unconscious bias include gender bias, cultural bias, race/ethnicity bias, age bias, language bias and institutional bias. Decisions made based on unconscious bias can compound over time, to significantly impact the lives and opportunities of others affected by the decisions" [59].

To help targeting your potential unconscious biases and their possible impact on design, some questions may help you to pinpoint potential blind spots as a team and as an individual.

THE TEAM COMPOSITION

- Who designs?
  Are my team members similar to me?
  - Completely
  - Mostly
  - Slightly
  - Not at all

- Which population groups <u>are not represented</u> in my team?
  (e.g., women, elderly individuals, Indigenous people, youth, individuals with disabilities, immigrants, individuals with low income, etc.)

- Based on the population groups that <u>are not represented</u> in the team, what blind spots might we be prone to in the design of our project?

- Which population groups are we at risk of excluding in our design?
  - Why?

- Could the absence of this or these groups have an impact on the design of our project?
  - If so, which ones?

YOUR BEHAVIORS

- Do I tend to believe I have no biases although I can perceive them in others?

- Do I tend to retain only information that sustains my opinion and my vision?
- Do you tend to rely on your first impression or how you feel about something or someone?
- Do you tend to design a product or a process to respond to your need or your team members' needs?
- Do I tend to dismiss some realities that are not mine?
- Do I tend to find it complicated to consider needs from realities of people I am not familiar to? (e.g.: The needs of women while I'm a man. The needs of people with disabilities while I don't have any disability. Etc.)

PROJECT DEVELOPMENT	STEP 2 : PREPARATION – ANALYSIS			
	2.1 Identifying needs and the problem	**2.2 Consulting**	**2.3 Looking for solutions**	**2.4 Development of possible solutions**
	- What is the problem? - What needs are we addressing? ○ What is the nature of the need? (e.g., psychological, social, physiological,	- Have you reached out to the impacted groups equitably? - Do certain groups hold knowledge (e.g., because of gendered or age-specific divisions of	- What are the mandatory specifications? - Which specifications can be set aside? ○ Why?	- Have you issued different recommendations to the client based on the GBA+? - How do the different solutions address the identified objectives and constraints?

	technical, temporal, financial, others?) - Who expressed this need? (e.g., company, users, a non-profit organization, etc.) - Why was this need expressed? - Who will use the product or process designed? - Have you conducted research to better understand the characteristics of the targeted groups in the project? - Is the social and human environment of the project characterized by the needs of a specific target group (e.g., women, elderly individuals, youth, immigrants, Indigenous people, etc.)? ○ If yes, do we have data broken down by sex or gender for this target group? ○ What insights emerge from the collected data? Are there significant differences between women and men? - What is the socio-economic context that generates movements by gender in this target group?	labor) with the potential to prevent unwanted outcomes, such as increased social inequalities or environmental damage? - Have you sought the opinions (e.g., reports, phone consultations, surveys, studies, etc.) of experts, community groups, or academic specialists on equity, diversity, and inclusion issues related to your project? - Have you consulted with a variety of stakeholders beyond your initial client? - Might different groups of potential consumers (e.g., non-binary individuals, women, or men, old or young, etc.) have different expectations regarding the project, product or interface? ○ Do certain features of previous innovations reinforce existing gender inequalities, gender norms, or stereotypes?	- What are the goals, objectives, outcomes, intentions, interests, and opportunities sought by each of the stakeholders? - What will be the utility of the product? For whom? What is its purpose? - What will be the project's action? ○ On whom? On what? How? - Have gender and other sociocultural issues been considered in long- and short-term project and planning goals? - What would be the characteristics of an ideal solution? - How can the needs evolve? - What body factors are considered during design? Is it representative of the entire population? (extremes/mean)	- Have you explained to your client the consequences of a scenario if it does not consider the GBA+? - Have you explained to your client who will benefit from the advantages of the proposed solution? - Is it more cost-effective to tailor the product to specific groups at early development stages or could it be inexpensively adapted in post-development?

	- In what ways could the designed product or process impact women and men differently? - Are there further anatomical and physiological differences between women and men that should be considered (e.g., in vision, hearing, voice pitch, sense of touch, smell, and taste, proprioceptors, muscular tension, temperature perception, etc.)?		- Which disabilities are considered? Are there specific physical requirements to use this design? (hearing, strength, color-blind) - Can someone from a different country understand how to use the design? If applicable, can their accent be a limitation? - Is the product adapted to different shades of skin color? - Is the product intuitive? (age, gender, disabilities)	

PROJECT DEVELOPMENT	STEP 3 :IMPLEMENTATION – INTEGRATION		
	3.1 Designing : choosing one solution	**3.2 Communication**	**3.3 Implementation**
	- Design to avoid other stereotypes relating to the roles and responsibilities of both genders being generated, confirmed or reinforced by the product or the project.	- With what medium is the project communicated to the population? - Does everyone have access to this information equitably? (young/elderly, different communities)	- Make sure that the resources and financial means devoted to the project or product respect the design decisions - Who is building the designed product or infrastructure? (population demographic)

	- Establish an action plan and methodology to reduce or even eliminate the impact of different factors such as gender, age, body factors, disabilities, language and voice, and skin color. - Ensure that diverse people benefit from equitable conditions and criteria for access to resources and to the benefits of the project or product developed.	- According to the project circumstances, have you integrated a diversity of individuals in the images used? - Have you written your texts in a gender-neutral manner? - Have you conveyed your messages in a way that they appeal to both women and men?	- Who is the building stage affecting? Does it disadvantage a portion of the population? (roads blocked, usage of a raw material) - Which steps are critical for human interaction and use?

PROJECT DEVELOPMENT	STEP 4: PROJECT ASSESSMENT – IMPACT OF RESULTS
	4.1 Disposition
	- After the implementation of the design, what data is collected? - Who uses the product or infrastructure? - Is their data related to consumer’s experience? Is there data for the entire population demographic? - Are there unnecessary features to be removed in a new version? - Are there missing features? - The validation of a design can be at least verified by checking it is adapted to the six categories identified ((1) sex and gender, (2) age, (3) body factors, (4) disabilities, (5) language and voice, and (6) skin color), based on data collecting their experience. - If a design is not adapted to one of those factors, it is relevant to address it and explain why it is not a specification for the design.

FURTHER STEPS

Once the preliminary version will be developed, the inclusive design support tool will be reviewed by design professors and instructors (January to February 2024) to be able to propose a revised version in March 2024. In the meantime, the team will begin designing the digital version of the tool with the support of specialists from the training support center (UdeS) so it can be user-friendly. Another objective is to keep the tool alive knowing that EDI concepts and needs related constantly evolve. Ultimately, the tool will be issued as an open educational resource so that other universities can use or adapt it.

Conclusion

Through the creation of a digital tool for inclusive design assistance and its concepts taught in an educational context, we aim at enhancing our students' skills to create designs adapted to our evolving and diversified society while considering their impact on different groups.

So far, our research has demonstrated the pedagogical relevance of developing the tool in the engineering Canadian context. It will enable us to better equip future engineers to address diverse needs while considering the differentiated impact on population groups. The development of this tool addresses a need to strengthen skills by concretely and innovatively integrating EDI into the training of future engineers. By enhancing these attributes, we are contributing to the development of enriched and more robust programs for future generations of engineers.

Furthermore, we have examined six categories of diversity factors, demonstrating the relevance of considering them, as this enhances the design processes. Literature reviews have also allowed us to initiate the iteration of a preliminary version of the tool by formulating key questions to be addressed during the design process.

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