The Empathetic Engineer: Strategies to Enhance Social Competence in Engineering for Wicked Problem Solving.

By

Eric Wilson

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We acknowledge and respect the Lək̓ʷəŋən (Songhees and Esquimalt) Peoples on whose territory the university stands, and the Lək̓ʷəŋən and W̱ SÁNEĆ Peoples whose historical relationships with the land continue to this day

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Abstract

Is engineering design education in North America adequately preparing students to tackle the major issues of our time? In today's political and social climate, engineers are essential members of multi-disciplinary teams addressing complex problems like poverty, climate change, the housing affordability crisis, resource depletion, and water shortages. These problems are "wicked"—complex, dynamic, and interconnected. To effectively address issues at the intersection of technology and society, engineers must have a deep understanding of both technical skills and human factors, including empathy. Given today's challenges, incorporating social competencies and emotional intelligence (EI) into engineering education and practice is more crucial than ever, particularly in engineering design. However, literature indicates that some efforts to cultivate more empathetic engineers have backfired, causing cognitive dissonance and rejection of these essential concepts.

The definitions of "engineering design" by the Canadian Engineering Accreditation Board (CEAB) have evolved over the years. However, the exclusion of non-technical competencies—such as empathy, communication, innovation, and creativity—remains a significant gap in engineering education and practice, hindering engineers' ability to address complex issues effectively. The engineering industry has noted deficiencies in the social competencies of engineering graduates, particularly in EI.

This dissertation aims to explore how the social competencies of engineering students can be enhanced to better prepare them for addressing the 'wicked' challenges they will encounter as industry professionals. This was done by integrating design thinking and systems thinking frameworks into a participatory learning environment to enhance EI among fourth-year engineering students at the University of Victoria. The intervention, a course titled "Infrastructure Design with Indigenous Communities," was carefully re-designed based on theories of identity formation and best practices from educational psychology to avoid some of the pitfalls noted in the literature.

The EQi2.0 inventory was used as the qualitative instrument to track changes in students' EI. The EQi2.0 measures emotional intelligence on a scale from 60 points to 140 points. A low range is defined as having a score of less than 90 points. A mid-range is defined as a score between 90 points and 120 points, and a high range is 120 to 140 points.

Statistical analysis of pre- and post-semester EI data from 17 students revealed statistically significant increases in overall EI. Results indicated an average overall EI increase of 5.4 points, with a calculated t-value of 3.105 and a p-value of 0.0034, thus rejecting the null hypothesis that the course had no effect on students' EI. Qualitative data from self-reflective papers supported the hypothesis that the course positively impacted students' EI. Students attributed their positive changes to experiences such as cultural acumen training, experiential learning activities, and direct engagement with partner First Nation communities.

Future research should include a control group to quantitatively validate that the intervention led to the increase in EI. Additionally, further examination of the EQi2.0 inventory is necessary to ensure its reliability in measuring EI, providing a more comprehensive understanding of the impact of such interventions on engineering education.

Despite acknowledged limitations, this study suggests that carefully integrating design thinking and systems thinking into engineering curricula, along with cultivating engineering professional identity development, holds promise for elevating EI in students. This approach may better equip engineers to engage with contemporary engineering challenges.

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This dissertation is based on the following published manuscripts:

i. Wilson, E., & Mukhopadhyaya, P. (2022). Role of empathy in engineering education and practice in North America.". Education Sciences, 12(6). https://doi.org/10.3390/educsci12060420

ii. Wilson, E., Dunne, D., Bergen, T., & Mukhopadhyaya, P. (2024). Reframing engineering design: integrating design thinking and systems thinking in engineering education and practice to address wicked problems. Canadian Journal of Civil Engineering, 1 - 14 dx.doi.org/10.1139/cjce-2023-0433.

iii. Wilson,E., Dunne,D. Bergen, T., & Mukhopadhyaya,P.(2025) Emotional Intelligence in Engineering Education Exploring the Influence of Empathetic Design Approaches in a Fourth-year Engineering Class. Canadian Journal of Civil Engineering, 52(6): 1204-1224 https://doi.org/10.1139/cjce-2024-0292

iv. Wilson,E. Dunne,D. Bergen, T. & Mukhopadhyaya.P. (2024) Importance of Empathy and Cultural Collaboration in Building (and Rebuilding) Thriving Communities. New Horizons in Civil Engineering Conference. Pending Publication

Acknowledgement

I would like to express gratitude to the individuals and organizations whose support and contributions made this research initiative possible.

First I would like to thank my family, whose unwavering support has helped me to persevere through this long academic journey and the many concurrent life changes. I would like to acknowledge my wife and the sacrifices she has made in order for me to be pursue my post-secondary educational to its finality. There were many circumstances that would have made it easier and more convenient to stop; not least of which was the birth of our children and the fact that this work happened (in-part) during an unprecedented global pandemic.

Thank you to my children for becoming my motivation. Not only to finish this dissertation so I could provide for your needs, but for motivating me to do my small part to make the future a better place where you can thrive.

During my academic career I have been fortunate to have had the support of many mentors who encouraged me in pursuing my interests. Dr. Mukhopadhyaya, thank you for guiding me and encouraging my interest in the less technical side of engineering. Dr. Dunne, thank you for opening your course in the Gustavson School of Business to engineering graduates. Your course on design thinking changed my career trajectory.

Terry Bergen, thank you for being my industry mentor at RJC Engineers, and seeing the value in me and my work. Your technical expertise, collaborative spirit, and insights have enriched this research project. I look forward to the continued work we will do together.

Eli Enns and Monica Shore, thank you for providing me with a space to explore an unconventional, “Hishuk-ish, Tsa-walk” approach to engineering based on empathy and interconnection. The support of

the IISAAK OLAM Foundation was invaluable throughout the duration of this project. The holistic, human-centered view of nature conservation, in-line with the values and teachings of Indigenous Protected and Conserved Areas aligns perfectly with the approach to engineering espoused in this dissertation, and I am grateful to have your partnership and friendship.

I would like to thank all the partners of the T'Sou-ke Housing Solutions Lab, Particularly T'Sou-ke First Nation and Gordon Planes for his enthusiasm and commitment to the project through the COVID-19 pandemic. Without your guidance and support as Chief of T'Sou-ke Nation, the project would not have succeeded and we would not be able to mobilize the knowledge and prototypes that arose from that project to the degree to which they have been.

I would like to extend special recognition and gratitude to Elder Mavis Underwood of the SȾÁUTW̱ First Nation for sharing the profound and enlightening story of Tetayut Creek. Your wisdom and cultural insights have added a unique and essential dimension to this work, and I feel deeply honored to have had the opportunity of learning from you. Tetayut Creek also holds a special place in my heart as I spent many hours as a child playing in the tranquil stream and learning from nature.

I would like to express heartfelt gratitude to the BC Housing Building Excellence Program, the CMHC Housing Solutions Lab Program, and MITACS for funding this project. The funders' commitment to advancing research in engineering, identifying challenges facing Indigenous communities, and their openness to the concept of human-centered design in engineering made these projects possible. I am grateful for their investment in this research project.

Thank you to the Emotional Intelligence Training Company for providing the EQi2.0 inventories and coaching to the students in my course. Your contributions made data collection and analysis possible.

In closing, this research project would not have been possible without the collaboration, guidance, and generosity of these organizations and individuals. I acknowledge their contributions with immense gratitude.

Preface

This doctoral dissertation follows a manuscript-based dissertation format and includes four peer-reviewed publications. While these publications are co-authored, this dissertation represents the original, individual work of the doctoral candidate, Eric Wilson. The manuscripts were developed as part of a research plan that is articulated throughout the dissertation.

Below is a description of each manuscript and the specific contributions made by the candidate and the co-authors.

1. **Wilson, E., & Mukhopadhyaya, P. (2022). "Role of empathy in engineering education and practice in North America." Education Sciences, 12(6).** https://doi.org/10.3390/educsci12060420

Candidate's Contributions:

- Conceived the research question.
- Conducted the literature review and critical analysis and synthesis.
- Performed thematic coding using NVIVO.
- Wrote the manuscript, including the creation or adaption of all figures and tables.
- Managed the peer-review revisions.

Co-authors' Roles:

- Corresponded with the journal. (Mukhopadhyaya)
- Provided supervisory feedback on research scope and manuscript structure. (all)
- Reviewed drafts and offered editorial guidance. (all)

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2. **Wilson, E., Dunne, D., Bergen, T., & Mukhopadhyaya, P. (2024). "Reframing engineering design: Integrating design thinking and systems thinking in engineering education and practice to address wicked problems." Canadian Journal of Civil Engineering.** https://doi.org/10.1139/cjce-2023-0433

Candidate's Contributions:

- Conceived the idea for the manuscript and drafted the full manuscript outline.
- Conducted a literature review on CEAB definitions of engineering design.
- Led the analysis contrasting traditional engineering design approaches to design thinking and systems thinking frameworks.
- Wrote the manuscript, including the creation of adaption of all figures and tables.
- Managed the peer-review revisions.

Co-authors' Roles:

- Corresponded with the journal (Mukhopadhyaya).
- Provided feedback on alignment with industry practice (Bergen)
- Provided guidance on design thinking and systems thinking frameworks (Dunne)
- Reviewed drafts and offered editorial guidance (all)

3. **Wilson,E., Dunne,D. Bergen, T., & Mukhopadhyaya,P.(2025) Emotional Intelligence in Engineering Education Exploring the Influence of Empathetic Design Approaches in a Fourth-year Engineering Class. Canadian Journal of Civil Engineering, 52(6): 1204-1224 https://doi.org/10.1139/cjce-2024-0292**

Candidate's Contributions:

- Designed and adapted the course intervention as noted.

- Designed the research approach, secured ethics approval, created partnerships with EQi2.0 professionals to support the study.
- Co-delivered the course intervention.
- Collected both quantitative and qualitative data.
- Conducted statistical analysis and qualitative analysis. Coded the qualitative data using grounded theory methods.
- Authored the full manuscript including data interpretation, tables, and visuals.
- Managed the peer-review revisions.

Co-authors' Roles:

- Corresponded with the journal (Mukhopadhyaya).
- Supported course approval and departmental coordination (Mukhopadhyaya)
- Supported ethics application (Mukhopadhyaya).
- Provided feedback on alignment with industry practice (Bergen)
- Provided guidance on design thinking and systems thinking frameworks (Dunne)
- Reviewed drafts and offered editorial guidance (all)

4. **Wilson, E., Dunne, D., Bergen, T., & Mukhopadhyaya, P. (2024). "Importance of Empathy and Cultural Collaboration in Building (and Rebuilding) Thriving Communities." New Horizons in Civil Engineering Conference (pending publication)**

Candidate's Contributions:

- Applied for and received grant funding for the T'Sou-ke Housing Solutions Lab.
- Assembled the team that implemented the T'Sou-ke Housing Solutions Lab.
- Authored the full manuscript.

- Conducted background research on Indigenous housing policy and synthesized findings.
- Created or adapted supporting visuals and tables.

Co-authors' Roles:

- Corresponded with the NHICE conference hosts (Mukhopadhyaya).
- Provided feedback on alignment with industry practice (Bergen)
- Provided guidance on design thinking and systems thinking frameworks (Dunne)
- Reviewed drafts and offered editorial guidance (all)

Introduction

In the 1960s, the Department of Indian Affairs and Northern Development (DIAND) began plans to replace a deteriorating clear-span bridge in SȾÁUTW First Nation (pronounced ‘say-out’, an Indigenous Community of the WSÁNEĆ (Saanich) Nation on Southern Vancouver Island. The bridge spanned approximately 100 feet over a small stream called Tetayut Creek. In the 1960's “the aging wooden bridge was in need of repair and with the growing population and the introduction of a municipal sewage plant at the Tsawout spit area the new innovation was introduced to bring in a paved road over two large culverts” (Underwood, 2023). Without consultation with the Nation, DIAND made the unilateral decision that a culvert system and road should replace the bridge.

Unfortunately, the newly installed culverts “also began to deteriorate quickly and the passage of water was slowed” (Underwood, 2023). This caused a large, still pool to form behind the culverts. Sediment, which would have ordinarily flowed into the estuary along with nutrients from the upper watershed, prematurely dropped from the slow-moving water and began to accumulate at the bottom of the pool, covering the loose gravel of the stream bed in a thick layer of sludgy silt.

Loose gravel is essential for spawning salmon, who dig into the gravel to lay their eggs. The accumulation of nutrient-rich sediment smothered any eggs that were present in the stream and destroyed the salmon spawning grounds. Also, the accumulations of debris “would build up and make it very easy for incoming salmon to be picked up by growing populations of otters and raccoons who guard the culvert system” (Underwood, 2023). The once productive salmon-spawning grounds are now empty. The yearly salmon run has disappeared.

In addition to the loss of the spawning grounds, the nutrients that would have flowed into the small estuary are now trapped behind the culverts, starving the once productive clam-gardens. Sediment that does make it through the culvert system is contaminated with pollutants from the farm-lands and

highway upstream of the Tetayut estuary – contributing to the permanent closure to shellfish harvesting in the Saanichton Bay and extinguishing another traditional food source and infringing on SȾÁUTW̱ First Nation's Douglas Treaty Rights to carry on their fisheries "as formerly".

In the early parts of the 1950s, "the bridge fostered many romantic encounters of young couples meeting under the bridge and watching the salmon return. The "salmon return was welcomed as an opportunity to maybe snag a fish deposited on the sandbar at low tide, [or] from time to time to capture an opportunistic octopus that was trying to follow the salmon in" (Underwood, 2023). Before the culverts, SȾÁUTW Nation members could paddle their canoes up into the watershed at high-tide. This was "a place that held particular cultural significance as it was a place for young men to come to as they were entering into the 'voice-change' period of puberty. They could explore and learn to control the growing resonance of their voice in the natural amphitheater of Tetayut Creek where the saltwater and freshwater merge and transform habitat for salmon and other important food systems" (Underwood, 2023). The location facilitated knowledge transfer between Elders and youth. With the installation of the culverts, Nation members could no longer enter the water shed to practice this tradition. They could also no longer practice ritual bathing and cleansing in the waters (Underwood, 2023).

In the story above, the installation of infrastructure with indifference to, or a lack of an understanding of cultural and environmental nuances destroyed cultural traditions, food-sources, and disconnected Nation members from their oral traditions and traditional territory and ways of life. The loss of tradition, culture, and connection to traditional territory has been shown to have cascading effects, leading to socio-economic challenges for Indigenous peoples. These outcomes stem directly from Indian Act legislation that impacts how infrastructure is design and delivered in Indigenous communities, and from a lack of empathy and understanding by the engineers working on projects such as the one described above.

Mavis Underwood highlighted the impact of Indian Act legislation on the SȾÁUTW̱ community:

"Due to the conduct of the Indian Act in our communities, we often had no say in how development intruded on our way of life and were often not informed about the intrusions of infrastructure, additionally as we are moving deeper into indigenous governance and administration we are finding we have been challenged by looking for basic plans of infrastructure and searching for ways and means to replace aging infrastructure. This has been extremely frustrating to have to search out the routes of infrastructure and to realize often that infrastructure did not accommodate planning or consideration not only of culturally significant areas but also did not plan for maintaining vital water systems, groundwaters, creeks, streams, [and] estuary areas" (Underwood, 2023).

The story of the SȾÁUTW̱ First Nation bridge replacement reflects the characteristics of a "wicked problem". As described by Rittel and Webber in 1972, a wicked problem has 10 defining criteria (Rittel & Webber, 1973) (however, it is not imperative that all criteria are present to define a problem as wicked). The criteria area:

1) There is no exhaustive formulation of a wicked problem.
2) Wicked problems have no stopping rule.
3) Solutions to wicked problems are not true-or-false, but good or bad.
4) There is no immediate and no ultimate test of a solution to a wicked problem.
5) Every solution to a wicked problem is a "one-shot operation"; because there is no opportunity to learn by trial-and-error, every attempt counts significantly.
6) Wicked problems have no clear list of possible solutions, nor a defined set of steps to follow when developing a solution.
7) Every wicked problem is essentially unique.
8) Every wicked problem can be considered to be a symptom of another problem.

9) Wicked problems can be explain in numerous ways. The choice of explanation determines the nature of the problems resolution
10) The planner has no right to be wrong.

The story above can be analyzed against these criteria to justify its classification as a wicked problem. Key elements from the story that align with Rittel and Webber's criteria include:

1. No Exhaustive Formulation of the Problem

While the concept of replacing the deteriorating bridge with culverts may have seemed like a straightforward solution to the problem, the downstream consequences (environmental degradation, loss of cultural practices, and associated socio-economic impacts) were not immediately apparent or considered. The up and downstream impacts offer many potential “frames” to the challenge.

2. No Stopping Rule

While culverts were introduced as a solution to the deteriorating bridge and lack of infrastructure services to the community, they created a new set of challenges that remain unresolved to this day. The degradation of the ecosystem, the loss of salmon spawning grounds, and the impact on cultural practices continue to unfold with no clear endpoint. While the original challenge of access and infrastructure into the community may have been solved, it has created many other challenges that now require solutions.

3. Solutions are Not True-or-False, but Good or Bad

The culvert system addressed the immediate infrastructure need (a road for growing population demands and infrastructure services), but at the cost of significant environmental and cultural harm. This demonstrates how solutions to wicked problems are subjective and evaluated by their broader

consequences rather than binary outcomes. When considering the criteria of cultural and environmental preservation, the culverts are a bad solution to this complex challenge.

4. No Immediate or Ultimate Test of a Solution

While the immediate infrastructure need may have been met, the long-term effects of the culvert installation took years to manifest. By the time the environmental damage and cultural loss were evident, reversing the damage became far more complex. This contributes to criterion number 2 and number 3.

5. One-Shot Operation with Significant Consequences

Infrastructure projects such as this are costly and not easily reversed. In addition, it was implemented using tax-payer dollars through the Canadian government. In all regards, the culvert installation was a "one-shot operation". There was no appetite to reverse course. Its negative effects on environmental degradation and cultural disruption became deeply rooted. The consequences on socio-economic outcomes stemming from the disconnection from traditional territory and cultural practices are well documented in the literature.

6. No Exhaustive Set of Solutions

The complex connections between historical context (relations between Indigenous and Crown governments), government policy stemming from the Indian Act, environmental conservation, infrastructure needs, and cultural considerations means there is no clear, singular solution. The problem can be framed from many perspectives.

7. Uniqueness of the Problem

While other communities may face similar challenges, the combination of the unique geography, cultural significance, Douglas Treaty Rights violations, and ecological disruption makes this case distinct.

8. Symptom of Another Problem

Taken to its head-waters, this is not an issue of a deteriorating bridge. It is an issue is about Crown/Indigenous relations, Treaty rights, and responsibilities. The culvert installation is not an isolated issue; it reflects broader systemic problems rooted in Indian Act legislation, colonial decision-making processes, the exclusion of Indigenous voices in infrastructure planning, and an ad-hoc approach to government funding of infrastructure on-reserve.

9. Multiple Explanations for the Problem

As mentioned above, the solution of installing the culvert system could have been "framed" in a multitude of ways. Some may attribute the need for the culvert system to failure of the bridge or poor engineering design. Others may emphasize the lack of initial consultation, cultural insensitivity, or implications of colonial policy. The chosen explanation shapes potential solutions.

10. The Planner Has No Right to Be Wrong

Engineers and decision-makers working within Indigenous communities carry a significant responsibility, particularly when the voices of key rights-holders have been excluded from the process. As this story highlights, the consequences of their designs and decisions can be far-reaching, resulting in socio-economic burdens for Indigenous peoples. As outlined in Criterion 5, infrastructure projects are often one-shot operations. When these projects fail, the impacts also extend beyond the immediate community. They place additional strain on public resources through increased government spending on social programs required to mitigate the resulting challenges.

This story highlights why engineers must have the skills to consider both technical and social aspects of a challenge when developing solutions. The infrastructure projects that engineers design and deliver do not exist in isolation. They become part of complex systems. It is important to consider and respect the

relationships between different components, stakeholders, and rights-holders of the system (both human and non-human) and determine how and why they affect one another, rather than focusing on individual parts (such as the provision of a culvert) in isolation.

It is vital for engineers working in these contexts to be aware and respectful of the intimate system of connections between infrastructure, culture, historical context, and the environment. They must have an understanding of "wicked problems" and the interconnected and empathetic approach to design that they demand to produce meaningful solutions.

Research Question

As will be discussed in detail in the following chapters, the scholarly literature on engineering education is clear: engineering education is not providing students with the social competencies needed to properly engage with wicked challenges. This dissertation is organized into five chapters. Chapters 1 - 3 examine the current state of engineering design education and practice and its ability to address wicked problems such as the one described in the story above. These chapters aim to address the question:

How might we improve the social competencies of engineering students to *prepare them to address the 'wicked' challenges that they will face as industry professionals?*

Chapter 4 outlines future work to address the limitations of this study.

Chapter 5 provides a case study example of the implementation of design and systems thinking in engineering practice related to the co-design and delivery of housing in Indigenous communities.

Research Objectives

The research question as provided above was explored in three parts:

Part 1: Explore conceptualizations of empathy, professional identity, and design in engineering education.

- RO1.1: Identify how social competencies, namely empathy, is conceptualized within engineering education through an in-depth literature review.
- RO1.2: Identify the perceived barriers to incorporating greater training of social competencies into engineering education

Part 2: Identify deficiencies in engineering education.

- RO2.1: Identify deficiencies in the Canadian Engineering Accreditation Board's definitions of 'engineering design' and explore methodological frameworks that could improve engineering design education.

Part 3: Synthesize findings to improve social competencies in engineering and implement a first iteration prototype design course.

- RO3.1: Identify how engineering design education could be improved to foster the development of social competencies in the students to better prepare them to engage with wicked problems.
- RO3.2: Develop and implement a course on engineering design for wicked problems that integrates the findings from parts 1 and 2 to help students integrate social competencies (primarily empathy) into their professional identities as engineers.
- RO3.3: Determine how engaging with a design course developed from the insights from part 1 and part 2 of this study change quantitative measures of the students' social competence and their qualitative understanding of the place of emotional intelligence (including empathy) in engineering.

Dissertation Outline

At the outset of this study, the main focus was on empathy and how engineers perceived it as important to professional practice and education. Empathy is the ability to understand and share the feelings,

thoughts, and experiences of others. It involves putting yourself in someone else's position to recognize their emotions and perspectives, fostering compassion and connection. It is a fundamental skill and attribute in “design thinking” (also known as empathetic design). Design thinking is described in detail within this dissertation, but in summary, it is an approach to design that uses empathy to create a deep understanding of user-groups and stakeholders in order to produce meaningful solutions to complex challenges. Specifically, design thinking is an approach to problem solving intended to produce good solutions to wicked problems.

Initially, empathy within the context of engineering was the main focus of this dissertation in order to determine what barriers may be faced when aiming to incorporate the tools and methodologies of design thinking into engineering education and practice.

In the search for an empirical tool to measure empathy as part of an intervention designed to integrate design thinking into an engineering course, the scope of study was expanded to “emotional intelligence” (of which empathy is a sub-category). This more closely aligns with the notion of “social competencies” as highlighted in the literature.

Chapter 1 highlights the challenge: engineering education is not preparing students to engage with wicked problems. It outlines a desire in industry for academia to produce more empathetic engineers. This chapter presents a literature review to determine how empathy is conceptualized and perceived in engineering academia and industry to get a sense of potential barriers to increasing the social competence of engineers.

This chapter presents five themes that emerged from an in-depth literature review on engineers’ conceptualizations of empathy in education and practice (Wilson & Mukhopadhyaya, 2022). The themes that emerged were:

1. A solid theoretical conceptualization of empathy

2. A utilitarian view of empathy
3. A belief that engineering is inherently empathetic
4. A general recognition that empathy is important an inconsistent approach to teaching it as a core competency of engineers
5. A tendency to devalue empathy despite a recognition of its usefulness

The literature explored in this review suggests that engineering education focuses heavily on the development of technical competencies at the expense of social competencies (Wilson & Mukhopadhyaya, 2022). The engineering science model of engineering design education that is taught throughout North America is leaving students ill-equipped to address the wicked problems that engineers face in the 21st century (Wilson & Mukhopadhyaya, 2022).

It was noted that some interventions that intended to improve the empathy and social competence of students instead showed decreases in these areas (Cech, 2014) (Patterson, 2019) (Walther J. , Brewer, Sochacka, & Miller , 2019). This chapter concludes that future interventions aimed at integrating social competencies into engineering education must also focus on supporting students through any cognitive dissonance that may arise (Wilson & Mukhopadhyaya, 2022).

Engineering educators have a significant influence on the cultural elements, narratives, and epistemological assumptions of engineering students (Walther J. , Brewer, Sochacka, & Miller , 2019). As such, the locus of the change should center on one's own pedagogical approaches within engineering education that are influential in the creation of students' professional identification (Wilson & Mukhopadhyaya, 2022).

This chapter concludes with recommendations on how to proceed with interventions that address this challenge. It cautions that interventions must be implemented carefully, considering best practices in educational psychology and identify formation to avoid some of the pitfalls noted in the literature.

Chapter 2 conducts a gap analysis on the Canadian Engineering Accreditation Board's definitions of 'engineering design'. Engineers frequently encounter intricate, interconnected challenges at the intersection of both social and technical dimensions. Therefore, this paper presented epistemologies from design thinking and systems thinking that offer a promising approach to improve engineering design education and increase the social competencies of engineers. These methodologies, when rooted in empathy as intended, empower design teams and stakeholders to explore, co-develop, and test solutions to intricate issues at the intersection of technology and society (Wilson, Dunne, Bergen, & Mukhopadhyaya, 2024). They emphasize an empathetic and iterative process of problem framing, qualitative inquiry, and hypothesis testing to generate novel solutions.

This chapter concludes that integrating concepts from design thinking and systems thinking into engineering design courses may provide engineers with the important foundations for building empathy and a deep understanding of the context of a design challenge. This may help engineers to produce more meaningful solutions to complex challenges, "framed" and "reframed" in the needs of the systems actors most impacted by design challenges, driving innovation in engineering education and practice (Wilson, Dunne, Bergen, & Mukhopadhyaya, 2024).

Chapter 3 describes an intervention to the social competence gap noted in the literature. The intervention is a redesigned 4th year engineering course entitled "Infrastructure Design with Indigenous Communities". The intervention incorporates the suggestions from chapters 1 and paper 2 with the goal of increasing the emotional intelligence (EI) of fourth-year civil engineering students. The course was re-designed to specifically target the EI sub-categories of empathy, social responsibility, and emotional self-awareness and the composite categories of self-perception, self-expression, and interpersonal. This chapter presents both quantitative and qualitative results of this intervention on students EI as measured by the EQi2.0 emotional intelligence inventory and self-reflective writings respectively. The EQi2.0 inventory measures emotional intelligence on a scale from 60 points to 140 points. A low range

is defined as having a score of less than 90 points. A mid-range is defined as a score between 90 points and 120 points, and a high range is 120 to 140 points.

The results of this course show statistically significant increases in the measured EI parameters. The average increase in emotional intelligence was measured to be 5.4 points. Of particular interest to the authors, the results showed statistically significant average increases in the sub-categories of empathy, self-expression, and social responsibility of 3.17 points, 5.11 points, and 5.88 points respectively.

This chapter also provides a qualitative assessment of students' self-reflective writings gathered throughout the semester to provide additional validity and rigour to the quantitative results.

Chapter 4 describes future work that could be taken to improve the study in chapter 3. This chapter explores the confounding factors and limitations of the study. It discusses the potential impacts of self-selection bias, the lack of a control group, and the potential bias introduced by the emotional intelligence inventory itself.

Chapter 5 provides a case study of a real-world application of emotionally intelligent engineering in engineering practice.

Contributions to Engineering Education, Engineering Practice, and Society

The work outlined in this dissertation is of importance to engineering education, engineering practice, and society broadly for several reasons:

1) Provides a framework for empirical validation of educational interventions

This dissertation presents a method of empirical validation that can be replicated or modified to assess the impact of future interventions to improve social competencies in engineering education (RO3.1).

This dissertation moves from the theoretical to the pragmatic and presents a case-study on a course intended to improve the social competencies of engineers.

2) Addresses the gap in social competence

This dissertation offers a critical literature review and gap analysis that highlights how empathy is perceived and integrated (or excluded) in engineering education (RO1.1). This provides an understanding of the existing challenges and mindsets that may be encountered when attempting to address the social competence gap in engineering (RO1.2)

3) Provides education insight

This dissertation identifies gaps in the Canadian Engineering Accreditation Board's definitions of 'engineering design' and synthesizes insights from the scholarly literature on Teaching and Learning that Others can use as a framework when designing further interventions (RO2.1).

4) Addresses industry needs

This dissertation presents a framework for engineering education to meet the noted needs of industry and society. The aim of the intervention described in this dissertation is to produce engineers with greater emotional intelligence, including empathy, social responsibility, and self-expression (RO3.2)(RO3.3). This will improve engineering solutions to complex challenges, stakeholder engagement, business development, and teamwork amongst other factors (RO3.1).

5) Addresses wicked problems in engineering

The recommendations and interventions discussed in this dissertation provide a framework to better prepare engineers for these complex wicked problems (RO3.1). For society, the frameworks presented (which were shown to increase the social responsibility of engineering students) will prepare engineers

to better understand and engage with societal needs. The frameworks presented in this dissertation will contribute to better engineering solutions for the public good.

Chapter 1: Role of Empathy in Engineering Education and Practice in North America

The content in this chapter is published in the following publication: Wilson, E., & Mukhopadhyaya, P. (2022). Role of empathy in engineering education and practice in North America. “Education Sciences”, 12(6). doi:https://doi.org/10.3390/educsci12060420

1.1 Preface

This study explores the conceptualizations of empathy in engineering. The scope of the study focused on published academic literature that specifically mentioned empathy, social responsibility, and social competencies. As a result, studies that address these areas of interest through synonymous terminology such as “compassion”, “perspective taking”, “understanding”, “bias identification” or topics related to diversity, equity, inclusion, and indigenization may have been inadvertently excluded. A previous literature review (included in this study) on the topic notes that these “notions are embedded within the use of similar vocabulary” (Strobel, Hess, Pan, & Wachter Morris, 2013) such as “user’s needs”, and “compassion” (Hess, et al., 2012).

In addition, much of the progress towards addressing the challenge noted in this dissertation is being made outside the body of published literature and at the level of program and curriculum development, which may not be captured within the academic literature. As such, the published literature may present a bleaker picture of the state of engineering education that is warranted. The review has been expanded to include notable examples of works to improve social competence in engineering noted in the literature since this chapter was published in the journal of Education Sciences in 2022.

1.2 Abstract

Does engineering design education in North America prepare students to address the major issues of our time? In today's political and social climate, engineers are part of multi-disciplinary teams tasked with finding solutions to complex issues like poverty, climate change, the housing affordability crisis, resource depletion, and water shortages. By definition, these problems are "wicked". If engineers are to play a role in addressing issues that exist at the intersection of technology and society, they must have a deep understanding of both technical competencies and of human factors. They must have the ability to empathize. In consideration of today's social, political, and environmental challenges, it has never been more important to instill social competencies into engineering education and practice, particularly around engineering design. This chapter analyzes the previous literature on empathy in engineering education in North America and synthesizes the data to present the conceptualization that engineers have of empathy in education and practice.

1.3 Introduction

"One doesn't have to operate with great malice to do great harm. The absence of empathy and understanding are sufficient." - Charles M. Blow

As the world becomes more interconnected, engineers are increasingly confronted with ill-structured problems at the intersection of technology and society (Carroll, Wang, & Delaine, 2018). The problems that 21st century engineers face are "inescapably social and technical" (Walther, Miller, & Sochacka, 2017). If engineers are expected to play a role in addressing these issues they must have a deep understanding of both technical competencies and of human factors. Without such an understanding, intended results can diverge significantly from achieved outcomes. There are numerous examples of well-meaning initiatives where the achieved outcomes were diametrically opposed to intended results. Consider the following examples that demonstrate complexity, unpredictability, and a mismatch between the intent and the resultant impact.

1. Although there have been significant advancements in energy efficiency measures (both in primary source energy generation and end-user efficiencies) over the last 50 years in attempts to reduce energy use, global aggregate energy consumption has increased dramatically. In general, improvements in efficiency have led to increases in energy consumption, not decreases. This is known as Jevon's Paradox (Freire- González & Puig-Ventosa, 2015) . In North America, we consistently spend 0.72 % of GDP on lighting, a figure that has held constant since about 1700 (Tsao, Saunders, Creighton, Coltrin , & Simmons, 2010). Additionally, although there have been significant advancements in the way we build our homes, per capita heating energy consumption has not decreased with efficiency improvements (Borofsky, 2010). This has direct implications to global climate change. In the face of overwhelming scientific evidence of the impending detriments of global climate change, countries around the globe have banded together to set aggressive targets to reduce greenhouse gas emissions, then have persisted with the same objectives for continual economic growth that created the problem in the first place.
2) In her book "Dead Aid", Dambisa Moyo explained that even though one trillion US dollars in "development assistance" has been funneled into developing countries through numerous aid initiatives, "the recipients of this aid are worse off, much worse off. Aid has helped make the poor poorer and growth slower…millions in Africa are poorer today because of aid. Misery and poverty have not ended, but have increased because of Aid. Aid has been, and continues to be, an unmitigated political, economic, and humanitarian disaster for most parts of the developing world" (Moyo, 2009).
3) Although there have been efforts to address the growing housing crisis on-reserves and to address the cascading socio-economic consequences that come from it, housing outcomes for Indigenous peoples have been deteriorating year-over-year since the 1960's (Olsen, 2016). It is not an exaggeration to say that the current state of Indigenous housing is in a state of crisis (The

Standing Senate Committee on Aboriginal Peoples, 2015). Government intervention and oversight led to the creation of deplorable living structures made from government delivered packets of materials barely suitable to construct a rudimentary shack (Olsen, 2016). More recently, building designs that were inappropriate for the climatic regions in which they were built are continuing to lead to a mired of structural issues (Optis, Shaw, Stephenson, & Wild, 2012) (Olsen, 2016), health issues (Liddell & Guiney, 2015) (Robson, 2008), and socio-economic problems for the occupants (Liddell & Guiney, 2015) (Solari & Mare, 2010).

How is this possible? The examples above are “wicked” and wicked problems (i.e. ill-defined, complex and interconnected) demand a very different approach to produce solutions. Rittel and Webber suggest that the problems that the engineering science model trains engineers so solve are “tame” problems (i.e. are well defined and have definitive solutions) (Rittel & Webber, 1973). For a tame problem “an exhaustive formulation can be stated containing all the information the problem-solver needs for understanding and solving the problem” (Rittel & Webber, 1973). As described by Rittel and Webber, wicked problems are a "class of social system problems which are ill-formulated, where the information is confusing, where there are many clients and decision makers with conflicting values, and where the ramifications in the whole system are thoroughly confusing" (Buchanan, 1992). As Rittel and Webber explain: “the information needed to understand the problem depends upon one’s idea for solving it and one cannot understand the problem without knowing about its context; one cannot meaningfully search for information without the orientation of a solution concept; one cannot first understand, then solve” (Rittel & Webber, 1973). Society looks to engineers to help develop solutions to wicked problems, however, these problems can never be fully solved (Rittel & Webber, 1973) (Kolko J. , 2012). There is no defined end-state at which to arrive, therefor solutions cannot be right or wrong, only good or bad (Kolko J. , 2012). Solutions to wicked problems should not be taught of as ways to solve a problem, but rather to improve a situation. The impacts of wicked problems can be mitigated through a process of

design that emphasizes empathy, abductive reasoning, and rapid prototyping (Kolko J. , 2012). What is missing in these three cases presented above? It can be argued that the missing component is a true understanding of complexity, human behavior, culture, and mindset . It may be that the missing component is a framework or approach that puts empathy into practice in the formulation of solutions.

While Jevon's paradox is a challenge far outside the scope of being addressed by engineers alone, engineers could be integrated into multidisciplinary teams aimed at addressing the upstream causes of this increased energy consumption. These may include:

1) Designing for demand reduction to counter act occupant behaviours.
2) Encouraging behaviour and mindset changes through design and community planning.
3) Advocating for policy changes and incentives encouraging sustainable design and energy conservation.

While the challenge of aid, is again outside the scope of being addressed by a purely engineering solution, engineers engaged in humanitarian issues may be integrated into teams focusing on the development of locally driven solutions. Solutions that are co-created with communities and integrate a deep understanding of local contexts -- as opposed to designing for communities from an outsider's perspective with an outsider's biases. This would support the implementation of solutions based in local knowledge, helping to ensure solutions are readily adopted and create long-term impacts.

It is clear that engineers have the capacity to produce solutions that lie within the technical realm, but if society is placing its collective hopes, even partially, in engineers to help design a way out of the human-made problems such as global climate change, the question must be asked: are engineers adequately prepared to fully understand the human side of socio-technical issues and integrate them into solution concepts?

1.3.1 The Call for a More Empathetic Engineer

Since the 1960's, the approach to engineering education has been "heavy on science, light on design and practicality" (Goldberg, Somerville, & Whitney, 2014). Today, the culture of engineering is "fundamentally misaligned with the times" (Goldberg, Somerville, & Whitney, 2014). In recent years, professional bodies and engineering educations have been having discussions around what kinds of qualities future engineers must possess (Walther J. , Brewer, Sochacka, & Miller , 2019). A broader view of competencies that engineers need regarding knowledge, abilities, and ways of knowing is being adopted in an effort to change the public's perception of engineering by highlighting that, as a profession, engineers solve human problems and thereby improve the lives of people (Fila , et al., 2014). In order for the profession to evolve and meet the changing needs of society, engineers must be socially responsible (Bielefeldt & Canney, 2015). They must be able to understand the human dimension of engineering issues. Increasingly, empathy is gaining attention as a way to meet the changing demands of the profession. Empathy "plays an essential role in such social interactions within the personal and professional contexts" (Hess, Strobel, & Pan, 2016). The world is changing rapidly. We now face "substantial challenges that require the technical capabilities of engineers to be augmented with a broader view of how engineers think, feel, and show up in the world" (Goldberg, Somerville, & Whitney, 2014).

1.4 Materials and Methods

In order to find out how empathy is perceived in engineering practice and education in the literature, a literature review was conducted into the subject using engineering literature databases such as Compendex (Engineering Village – Elsevier Engineering Information), IEEE Xplore, and Geobase. This approach is consistent with the literature review done by Hess e*t al* in 2012. These databases were chosen because of their relevance to engineering subjects. Geobase was included to be consistent with

the review noted in 2012. A search for “empathy in engineering” received 785 records. Further refinement using a keyword search to include “students, human engineering, engineering education, product design, engineers, education, or design” narrowed this to 192 articles. In depth literature reviews on the subject were conducted in 2012 (Hess, et al., 2012) and in in 2013 (Strobel, Hess, Pan, & Wachter Morris, 2013), therefore, this initiative restricted the search to records published between 2012 – 2020. This limited the search results to 146 records (118 conference papers, 27 journal articles, and 1 book). To further refine the search, abstracts of the 146 records were reviewed to identify the records that 1) explicitly discussed the conceptualization of empathy in engineering education or practice, 2) discussed how engineering education changes student engagement with issues of social responsibility, 3) described the implementation of interventions intended to increase social competencies in engineering and directly measured changes in empathy through quantitative or qualitative means. This significantly narrowed the search as this is a fairly nascent research area. Much of the available literature on this topic is written by a relatively small number of authors, which may introduce bias into this synthesis exercise. In addition, this synthesis exercise focused on the North American context from a general perspective. In addition, much of the literature describes engineering as a monolith, however, there are statistically significant differences in the levels of empathy and social concern between the sub disciplines of engineering, with civil and environmental engineers rating higher than their peers in mechanical engineering (Bielefeldt & Canney, 2015).

A brief survey of a 2018 European study on global engineering competencies was reviewed to determine similarities and differences between the North American and European contexts.

1.5 Results

Despite the 785 records that mention empathy in engineering, there are very few entries that explicitly outline the conceptualizations of this phenomenon in engineering and describe the direct, measurable

impact of interventions on the empathy of engineers. This observation is also noted many times in the existing literature (Hess, Strobel, Pan, & Watcher Morris, 2017).There were 24 records that were read in-depth and synthesized using data clustering techniques and coding in NVIVO. NVIVO is purpose-built for qualitative and mixed methods research. It helps researchers organize, store, retrieve, and analyze data. NVIVO was used to aid in making connections between the selected documents and understand underlying themes and patterns in their content to inform and support decisions. Data Clustering techniques were also used to visualize the connections in the data.

There were several recurring themes within the papers that explicitly met the objectives of this review. Justification for the small number of selected papers is made based on data saturation in qualitative research. Much of the research that has been done has been of a qualitative nature. The studies in this review included between 7 and 146 participants. Studying data saturation and variability in qualitative inquiry, it was found that "saturation occurred within the first twelve interviews" and "basic elements for meta-themes were present as early as six interviews" (Guest, Bunce, & Johnson, 2006). Despite the fact that scholars seldom articulate their conceptualizations of the phenomenon of empathy in engineering, the articles that do are based on a rich source of data that includes qualitative interviews as well as previous literature reviews in order to triangulate findings and create generalizations on the conceptualizations of empathy within engineering through a grounded theory approach.

The following table (Table 1) shows the main themes that emerged from this synthesis.

Table 1 – Engineers' Conceptualizations of Empathy and its Place in Education and Practice

Themes	Key Cites	Example
A well-defined theoretical conceptualization of empathy	(Hess, et al., 2012) (Hess, Strobel, & Pan, 2016) (Strobel, Hess,	"[engineers] described empathy as perspective taking or imagining what another is experiencing and empathy as

	Pan, & Wachter Morris, 2013) (Hess, Strobel, Pan, & Watcher Morris, 2017)	embodiment or seeing the world from another's or others' viewpoint. Outcome-specific themes described empathy as interconnectedness with the surrounding world context and understanding another's or others' thoughts or feelings." (Hess, Strobel, & Pan, 2016)
A utilitarian view of empathy to improve abilities related to: • Communication • Leadership and management abilities • Attaining personal goals • Attracting and retaining diversity in education • Improving designs • Altruistic pursuits • Improving technical abilities • Promoting safety	(Walther, Miller, & Sochacka, 2017); (Bielefeldt, Zhao, Canney, Swan, & Knight, 2020); (Walther, Miller, & Kellam, 2012); (Hess, et al., 2012); (Strobel, Hess, Pan, & Wachter Morris, 2013); (Hess, Strobel, & Pan, Voices from the workplace: practitioners' perspectives on the role of empathy and care within engineering,	"This review of the literature presents empathy in engineering as, first and foremost, a means to an end, or 'tool to take off the shelf,' when there is likely to be some personal or professional benefit from doing so". (Walther, Miller, & Sochacka, 2017) "…. empathy and care enable one to accurately understand the view or perspective of colleagues and clients, including their thoughts and desires." (Hess, Strobel, & Pan, 2016) "The team can't work if you don't understand what the other

	2016); (Hess, Strobel, Pan, & Watcher Morris, 2017)	person is really thinking what drives them..." (Hess, et al., 2012) "…engineers we interacted with suggest empathy and care have the most value to engineers working in managerial or leadership roles." (Strobel, Hess, Pan, & Wachter Morris, 2013) "I think your chances of moving ahead, in whatever field of study you are in, are going to be better if you get along well with others." (Hess, et al., 2012)
The profession is inherently empathetic	(Walther J. , Brewer, Sochacka, & Miller , 2019); (Hess, Strobel, & Pan, Voices from the workplace: practitioners' perspectives on the role of empathy and care within engineering, 2016) ;(Strobel, Hess, Pan, & Wachter Morris,	"You could make an argument that pretty much all of engineering is about improving society, and therefore at some level there is some element of empathy and caring" (Strobel, Hess, Pan, & Wachter Morris, 2013) "… participants held several beliefs highlighting the fact

	2013); (Hess, Strobel, Pan, & Watcher Morris, 2017); (Hess, Strobel, & Pan, 2016); (Walther, Miller, & Kellam, 2012); (Hoople & Choi-Fitzpatrick, 2017)	that empathetic and caring traits exist in engineering already (primarily in the academic realm)." (Hess, et al., 2012)
A recognition of the importance of empathy but an inconsistent approach in teaching it as a core competency of engineers.	(Walther, Miller, & Sochacka, 2017); (Walther, Miller, & Kellam, 2012); (Walther J. , Brewer, Sochacka, & Miller , 2019); (Strobel, Hess, Pan, & Wachter Morris, 2013) (Hess, et al., 2012); (Patterson, 2019) (Hess, Strobel, Pan, & Watcher Morris, 2017);	"despite a growing recognition of the importance of empathy for contemporary engineering practice, the professional skills literature does not provide guidance on how to foster empathy in undergraduate engineering programs." (Walther, Miller, & Sochacka, 2017) However, scholars and educators have also recognized a range of challenges due to a scarcity of conceptual models and empirical bases that limit the broader integration of empathy into the discussion and practices of engineering educators and professional engineers (Walther J. , Brewer, Sochacka, & Miller , 2019)

		Empathy and care have a strong presence in engineering practice, although these terms have lacked conceptualization and a coherent framework for their application and development. (Strobel, Hess, Pan, & Wachter Morris, 2013)
A tendency to undervalue empathy within engineering despite a recognition of its importance	(Cech, 2014); (Patterson, 2015); (Brewer, Sochacka, Walther, & Miller, 2017); (Walther J. , Brewer, Sochacka, & Miller , 2019); (Strobel, Hess, Pan, & Wachter Morris, 2013); (Patterson, 2019) ;(Hess, et al., 2012); (Thomson, Wurtzburg, & Centifanti, 2015)	[empathy is] "Valuable, but not absolutely necessary" (Strobel, Hess, Pan, & Wachter Morris, 2013) engineers' ability to conceptualize the relationships between engineering work and public welfare is devalued compared to ''technical'' competencies because public welfare considerations are, by definition, on the ''social'' end of this dualism (Cech, 2014) "… this aspect of engineering is often downplayed as pertaining to necessary, but peripheral, 'soft' or professional skills". (Walther, Miller, & Sochacka, 2017)

1.6 Discussion

From this study it was determined that the conceptualizations of empathy in engineering education and practice as presented in the literature reviewed can be described in the following thematic points: 1) A solid theoretical conceptualization of empathy, 2) A utilitarian view of empathy, 3) A belief that engineering is inherently empathetic, 4) A recognition of the importance of empathy but an inconsistent approach in teaching it as a core competency of engineers, 5) A tendency to devalue empathy despite the recognition of its usefulness.

1. *A solid theoretical conceptualization of empathy*

Although the concepts of empathy are "uncommon in the vocabulary of engineers" (Strobel, Hess, Pan, & Wachter Morris, 2013), a previous literature review notes that these "notions are embedded within the use of similar vocabulary" (Strobel, Hess, Pan, & Wachter Morris, 2013) such as "user's needs", and "compassion" (Hess, et al., 2012). The previous literature reviews and the additional qualitative studies on empathy in engineering show that engineers have a good theoretical understanding of empathy. Engineers see empathy from the themes of both a process component and an outcome component (Hess, et al., 2012) (Strobel, Hess, Pan, & Wachter Morris, 2013). The process component was described as "perspective taking" – the ability to put yourself in someone else's shoes (Hess, et al., 2012), while the outcome component was about creating connectedness (Hess, Strobel, & Pan, 2016).

2. *A utilitarian view of empathy*

Within engineering, empathy is seen as "first and foremost, a means to an end, or 'tool to take off the shelf'" (Walther, Miller, & Sochacka, 2017). In large part, "empathy is seen as a tool to use to enhance professional communication with which to "handle 'difficult' stakeholders" (Brewer, Sochacka, Walther, & Miller, 2017) or "whenever a projects success depends on inter-disciplinary relations amongst engineers" (Strobel, Hess, Pan, & Wachter Morris, 2013). When considering the usefulness of empathy in engineering "most respondents attached the greatest value to economic gains' (Strobel, Hess, Pan, &

Wachter Morris, 2013) and that "empathy seems to be the means to attain personal goals such as becoming better in teamwork, communication, management, client relationships, and leadership" (Strobel, Hess, Pan, & Wachter Morris, 2013).

Additional perspectives showed that engineers perceived empathy as a means to increase diversity, improve design, promote safety, and even improve exiting technical abilities.

3. *A belief that engineering is inherently empathetic*

Although empathy is not frequently discussed in the engineering literature (at least by that term), one study shows that engineers frequently make the argument that the profession is inherently empathetic considering the roles engineers play in enhancing society (Hess, et al., 2012) (Strobel, Hess, Pan, & Wachter Morris, 2013) (Hess, Strobel, & Pan, 2016). Engineers perceive themselves as empathetic by providing solutions that benefit mankind (Hess, et al., 2012). The argument is that "pretty much all of engineering is about improving society, and therefore at some level there is some element of empathy" (Strobel, Hess, Pan, & Wachter Morris, 2013), and that effective engineers must have a certain level of trust and compassion to understand how designs fit into larger context (Hess, et al., 2012).

4. *A recognition of the importance of empathy but an inconsistent approach in teaching it as a core competency of engineers.*

Although empathy and care appear to have a place within engineering "it appears that conversations and awareness of these two constructs may not often be explicitly stated within the literature or frequently addressed by academic and professional engineers" (Strobel, Hess, Pan, & Wachter Morris, 2013). As mentioned above, these "notions are embedded within the use of similar vocabulary" (Strobel, Hess, Pan, & Wachter Morris, 2013) such as "user's needs", and "compassion" (Hess, et al., 2012). However, the literature showed some striking opinions about the relevancy of empathy in engineering education. Faculty interviews showed that empathy was, amongst other themes, "valuable, but not absolutely necessary" (Strobel, Hess, Pan, & Wachter Morris, 2013). One participant stated that

"…it's not part of the engineering culture" (Strobel, Hess, Pan, & Wachter Morris, 2013). The literature showed that faculty participants stated empathic skills are 'very, very important" but that it is not their job to teach students to be empathetic or caring, continuing that "we don't need a course on it" (Hess, et al., 2012). This is perhaps because this participant felt that its inclusion indirectly through other discussions is sufficient.

Engineering practitioners describe empathy as key to their profession practices in a variety of areas. They describe many positive outcomes of integrating empathy into engineering practice including: the creation of higher quality solutions, improved interpersonal relations, more effective leadership abilities, and higher motivation to help others". They also suggested that a "greater inclusion of empathy and care within the culture of engineering has the potential to improve engineering along multiple facets" (Hess, Strobel, & Pan, 2016). According to engineering practitioners "empathy and care tend to be overlooked or undervalued within engineering" (Hess, Strobel, & Pan, Voices from the workplace: practitioners' perspectives on the role of empathy and care within engineering, 2016) and there is a "profound need for integrating empathy and care into the education, training and (thereby) the practice of engineering" (Hess, Strobel, & Pan, 2016).

Walter et al note in 2019 empathy is being increasingly recognized for its central role in engineering, however, they note that scholars and educators have "recognized a range of challenges due to a scarcity of conceptual models and empirical bases that limit the broader integration of empathy into the discussion and practices of engineering educators and professional engineers" (Walther J. , Brewer, Sochacka, & Miller , 2019).

5. A tendency to devalue empathy despite a recognition of its usefulness

There is an overall devaluing of empathy and social competencies within engineering (Hess, Strobel, & Pan, 2016). While this is anecdotal, and not intended to be construed as evidence for this theme, perhaps the engineers reading this dissertation can recall times in their education or professional

practice where discussions of an emotional nature were prefaced by comments such as “we as engineers don’t normally talk about our feelings, but…”or a non-technical class that was seen as something to “get through to graduate”. The mindset behind this sentiment is described in depth by what one author in the literature refers to as a “culture of disengagement” (Cech, 2014). This will be discussed in greater depth below.

1.6.1 A “Culture of Disengagement”

The “culture of disengagement” (Cech, 2014) in engineering education as described by Cech, is a set of “beliefs, meanings, and practices” (Cech, 2014) that form the creation of professional identity and dominion of influence of an engineer. In turn, this culture frames “the day-to-day activities of problem definition and solution development, as well as more abstract understandings such as the meaning of engineering as an institution” (Cech, 2014). Cech suggests that this “culture of disengagement” (Cech, 2014) casts social concerns as illegitimate to the epistemologies of engineering. As a result, “public welfare commitments become less central to the student’s understanding of their professional roles the longer the spend within engineering training” (Cech, 2014). Once students are studying engineering, there is an emphasis on the development of technical capacities at the exclusion of other intelligences (Goldberg, Somerville, & Whitney, 2014). Cech posits that the “uniformity across diverse school contexts [and disciplines] in public welfare beliefs suggests that a culture of disengagement may be a profession-wide phenomenon in the broader culture of engineering” (Cech, 2014).

In the past, “the engineer’s assumed perspective was outside the situation or problem – that of a disengaged problem solver who could confidently model the problem in objective, mathematical terms and then project a solution, framed largely in terms of efficiency and technical ingenuity, affecting a system uncontaminated by the frictions of human relationships or conflicting purposes” (Strobel, Hess, Pan, & Wachter Morris, 2013).

From interviews of practicing engineers, one participant in a 2013 study commented on what it takes to be a successful engineer: “I think there’s a perception…to be really successful you have to be tough as nails and maybe suppress being a nice guy.” (Strobel, Hess, Pan, & Wachter Morris, 2013). One of the themes from the faculty interviews showed that empathy was seen as “valuable, but not absolutely necessary” (Strobel, Hess, Pan, & Wachter Morris, 2013) with one participant commenting that the place for empathy was in the “teamwork part of a design class”, a statement that shows a very narrow understanding of empathy and how it fits into other aspects of design such as problem definition, solution development, and prototype testing. Another participant claimed “Our classes are adamantly, adamantly, technical and that’s not going to change” (Strobel, Hess, Pan, & Wachter Morris, 2013) continuing that “[empathy] is not part of the engineering culture” (Strobel, Hess, Pan, & Wachter Morris, 2013).

Cech posits that in professional practice, engineers use a commonly held conceptualization of what an engineer is and does to decide what considerations are integral to their design responsibilities for a particular project and what considerations are tangential (Cech, 2014). As such, non-technical elements of a project may be defined out (Cech, 2014). This type of approach to engineering design projects leads to a variety of concerns not considered directly ‘‘relevant’’ to the achievement of technical objectives to be omitted and neglected. These concerns may include socioeconomic inequality, history, cultural context and global politics (Cech, 2014). Algra et al state that much of the literature on “human factors” in engineering implies that human factors are left to “someone else” or pushed to the end of the design process as a “last-minute add on” (Algra & Johnston, 2015).

It is interesting to observe that the literature on empathy in engineering shows a paradoxical interpretation of the need and place for empathy within engineering practice and education. On one hand, the profession seems to devalue ‘‘non-technical’’ concerns as irrelevant to ‘‘real’’ engineering work (Cech, 2014). At the same time there is a belief that engineering is inherently empathetic (Strobel,

Hess, Pan, & Wachter Morris, 2013). Further still, engineering practitioners recognized a multitude of benefits to empathy and stated that it has “the potential to improve engineering along multiple facets” (Hess, Strobel, & Pan, 2016).

An interesting trend is that increased years of work experience lead to a greater appreciation and recognition of empathy in engineering (Hess, Strobel, Pan, & Watcher Morris, 2017). However, engineers state that they did not learn to be empathetic in their college years (Hess, Strobel, Pan, & Watcher Morris, 2017).

While Cech’s work brings valuable attention to areas in engineering education needing improvement, her work may be overly critical and lack nuance in the contemporary climate of engineering education. Many programs integrate courses on ethics, community engagement, and interdisciplinary studies aimed at broadening students’ understanding of social context.

One must acknowledge that objectivity is undoubtedly a key definitional feature in some aspects of engineering decision making, and a very important one at that. An engineer performing the structural design of a bridge based on feelings would be irresponsible and potentially detrimental to public safety. If that bridge were to collapse, there would need to be a trail of factual evidence and calculation that could be examined to determine why. There is no need for empathy in the structural analysis of a beam, the design of a bolt pattern or the development of a foundation pile. These designs must be made objectively. Objectivity is needed in the development of solutions to “tame” problems (problems with a clear right and wrong answer).

1.6.2 The Impact on Engineering Students' Professional Identity Formation

Engineering education focuses on the development of technical abilities (Strobel, Hess, Pan, & Wachter Morris, 2013), training graduates to see the word from a technically focused mindset (Hoople & Choi-Fitzpatrick, 2017), leading to a devaluation of social competencies (Hess, Strobel, & Pan, 2016) (Cech, 2014). The consensus from the literature is that engineering schools could improve in training students in the realms of social competence (Brewer, Sochacka, Walther, & Miller, 2017). Narratives that arise explicitly or implicitly about what engineering is through the devaluation of social competencies may limit the ways in which students envision their future professional selves (Walther J. , Brewer, Sochacka, & Miller , 2019).

The model of engineering science that is prevalent in engineering schools today teaches students to apply scientific principles to technological problems; however, it produces graduates who have difficulty adapting their knowledge to complex real-world problems that are not as formulaic as the problems they face in text-books (Dimopoulos, Wilson, Bubbar, & Wild, 2018). In fact, engineering students spend much of the first two years of their programs devoted to basic sciences and mathematics (Dym, Agogino, Eris, Frey, & Leifer, 2005). While this is undoubtedly important, greater emphasis should be placed on the role of social competencies in engineering during the early, formative years of students' developing professional identities. The resulting engineering graduates from this style of engineering education have been perceived by industry to be unable to participate in the engineering problems faced by engineering professionals (at least in the recent past) (Dym, Agogino, Eris, Frey, & Leifer, 2005) that require a command of social competencies. Real world problems include a human element that one must navigate and understand.

While engineering programs do a fantastic job of training engineers with keen technical skills, real-world challenges also involve social competencies to navigate, cultural, and emotional dynamics that cannot be solved through formulas. Navigating these situations comes from a way of being. It often involves understanding diverse, sometimes conflicting interpretations of information and finding mutually agreeable ways to resolve conflicts. Empathy enables engineers to better understand the lived experiences, values, and needs of stakeholders within a project, or the people their designs will impact. By developing empathy, engineers can engage more effectively with stakeholders, ensuring solutions are not only technically sound but also socially responsible and culturally appropriate, and delivered amicably. These are examples of the empathetic skills that the participants in the study of Hess et al stated that they did not learn in their college years (Hess, Strobel, Pan, & Watcher Morris, 2017).

1.6.3 Attempts to improve social competencies in engineering education

Some attempts to improve the social competencies of engineering students are reported in the literature. An interesting case study in the literature showed that empathy and social considerations can decrease even in the face of interventions that attempt to improve social competencies (Patterson, 2019). This case was not large enough to produce generalizations from, however it suggests that there may be more to increasing levels of empathy in engineering than simply introducing more empathic learning modules, such as simultaneously attending to students' developing professional identities. This will be discussed in greater detail below.

Decreasing levels of empathy in the face of interventions (Cech, 2014) (Patterson, 2019) (Walther J. , Brewer, Sochaka, & Miller, 2020) may be explained by the presence of dominant cultural of disengagement as noted in this review. However, it may also be explained by ineffective pedagogies. Just as the three examples presented at the beginning of this article illustrate how gaps in the understanding at the systems level and at the level of human behavior can produce results diametrically

opposed to intended outcomes, the same is true for attempts incorporate empathetic perspectives into engineering. Justification for this conclusion can be found in motivational, emotional, and organizational theory on self-schemas and organizational identification.

Self-schemas are domain specific cognitive generalizations about the self that are learned from past experiences (Reeve, 2009). As students' progress through their engineering education, they adopt a self-identification with the cultural identity of an engineer (as presented actively and passively by their institutions). Theories from the domain of motivation and emotion show us that when confronted with information that conflicts with a deeply engrained self-schema, one will act to preserve previously held beliefs:

"Once an individual establishes a well-articulated self-schema in a particular domain, he will generally act to preserve that self-view. Once established, self-schemas become increasingly resistant to contradictory information (Reeve, 2009).

Attempts to instill empathy within engineers without considerations of how to manage the formation of professional identity may have instead acted to reinforce dominant cultural beliefs. This phenomenon is displayed in a study on the implementation of a series of empathetic communication modules. The authors note the following:

"when some students felt challenged by the experiences of the modules, the snapshot of their development provided by the written reflection revealed that they, at least temporarily, retreated more firmly to previously held assumptions. Similarly, other students reported a disconnect between their experiences of empathy as an individual and as a future engineer, and their reflections simultaneously showed conflicting views and perceptions". (Walther J. , Brewer, Sochaka, & Miller, 2020)

1.6.4 Connections to Motivational, Emotional, and Organizational Theory

The following figure shows the various paths that one can take through the processes of self-identification as one's self-identity as an engineer is challenged. This graphic has been adapted to the case of identity formation in engineering from the generalized model found in "Understanding Motivation and Emotion 5th edition" by Johnmarshall Reeve (Reeve, 2009).

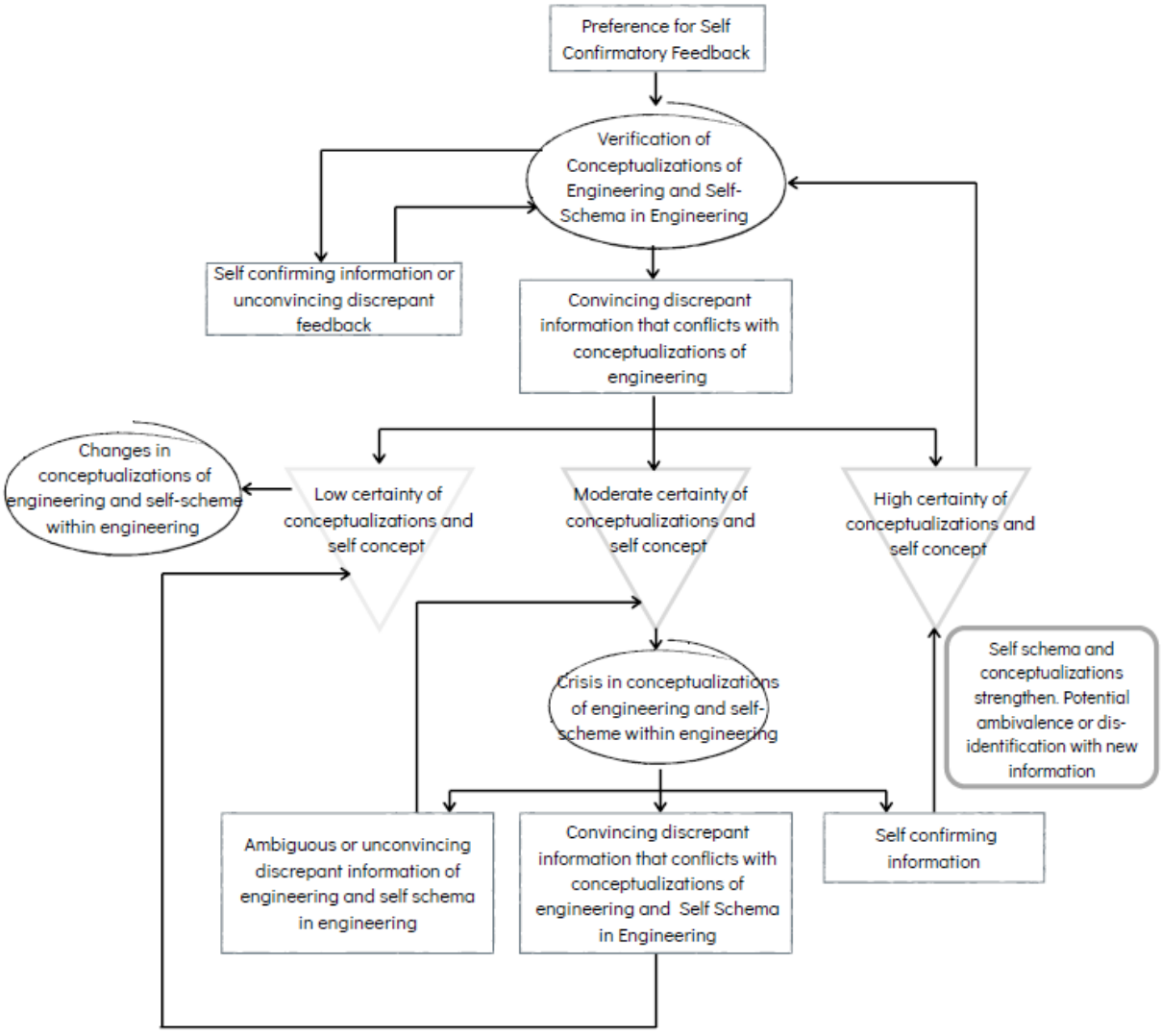


Figure 1 - Processes Underlying Self-verification and Self Concept Change Pertaining to Empathy in Engineering adapted from (Reeve, Understanding motivation and Emotion 5th edition, 2009)

Figure 1 shows that in the event that an individual's self-schema is sufficiently challenged to induce a self-verification crisis, but not challenged in such a way as to motivate the individual to seek additional information or produce a low certainty of self concept, previously held beliefs are reinforced as the individual seeks out self-validating information. In this case attempts to change the self-schema of engineers will backfire, potentially leading to a case where they begin to *disidentify* with the information - meaning the individual will begin to create part of his identify around a belief that runs counter to the information that created the crisis of self-concept (in the cases of the above interventions, the training of empathy within the engineering context). This is what Walther *et al* observed in the following passage:

> *"when some students felt challenged by the experiences of the modules, the snapshot of their development provided by the written reflection revealed that they, at least temporarily, retreated more firmly to previously held assumptions".* (Walther J. , Brewer, Sochaka, & Miller, 2020)

The difficulties encountered when trying to encourage students to identify with the concept of an "empathetic engineer" parallel difficulties encountered in studies of organizational change and organizational identification.

Michael G Pratt used an ethnographic study on Amway distributors to create a model of managing identification that shows the various social-psychological outcomes of this process. Like them or not, it is irrefutable that Amway has developed tactics to create a strong sense of positive identification within their (often times overzealous) distributors. In his study, Pratt highlights the practices and processes involved in managing organizational identification, specifically the processes of sensebreaking and sensegiving. Figure 2 is an adaptation of a figure from Michael G Pratt's article " The Good, the Bad and the Ambivalent: Managing Identification among Amway Distributors" and shows the process behind the tactics of creating organizational identification.

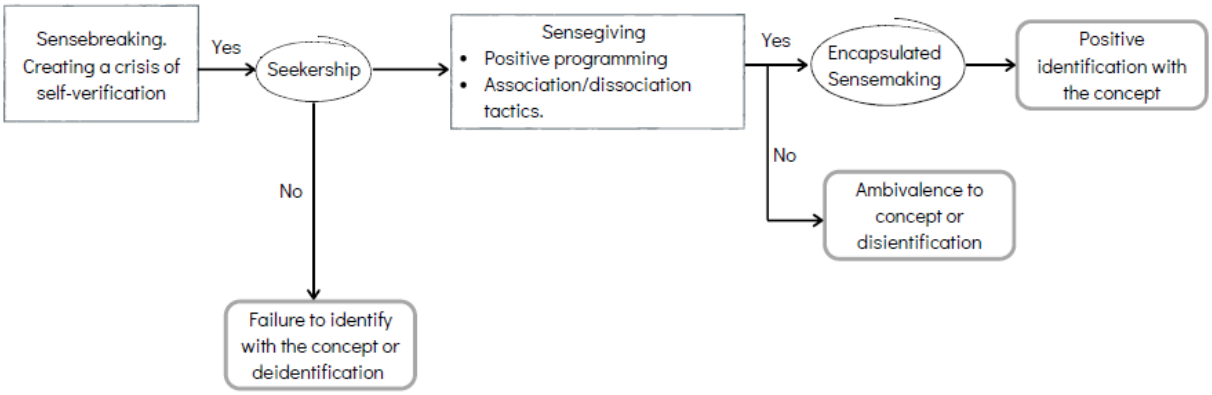


Figure 2 - Managing Identification and Sensemaking (Pratt, The Good, the Bad, and the Ambivalent: Managing Identification among Amway Distributors, 2000)

Pratt's work provided a "glimpse behind the curtain" at the psychological processes involved with creating positive organizational identification. Exploiting these processes could be used as a means to both nefarious and admirable ends.

It could be hypothesized that some of the interventions noted in the review may have unknowingly succeeded in 'sensebreaking' and created a self-verification crisis in the students. This is noted in many of the studies through a display of cognitive dissonance (Wong K. , et al., 2016); (Walther J. , Brewer, Sochaka, & Miller, 2020); (Brewer, Sochacka, Walther, & Miller, 2017); (Patterson, 2019); (Cech, 2014). Sensebreaking and a self-verification crisis may have occurred when the students were encouraged to self-reflect, confront their biases and perceptions of engineering, or were introduced to the concept of engineering as a profession that requires empathy and social competence. Sensegiving would have occurred through pedagogical approaches such as empathic communication, empathetic design, service learning, and facilitated student's engagement with an empathetic design project. Within these interventions, the students may have held a moderate self-identification with any established engineering culture (that may have excluded empathy and social competence). Students who received information convincing enough to induce a self-identification crisis without also being 'encapsulated' and supported in their sensemaking process would form, at best, an ambivalent identification with the

concept and at worst a disidentification and strengthening previously held beliefs. This result was noted explicitly by Walther *et al* through qualitative observation, and by Cech and Patterson through quantitative observation.

1.6.5 Successful Attempts to Instill Social Competence in Engineering Education

As discussed above, much of the work to address this noted gap have taken place outside the published literature at the level of program and course development and are not all reflected in the literature.

There are indeed groups encouraging future engineers to consider human factors and the "broader picture" of their designs. For example, the Centre for Socially Engaged Design at the University of Michigan's College of Engineering "empowers students and practitioners with perspectives and skills needed to design effective technology interventions that are good for the world" (Center for Socially Engaged Design, 2019). They do extensive research to inform socially engaged design principles and methodologies. Through their Socially Engaged Design Academy they encourage students to integrate human considerations into engineering design.

In addition, the book "A Whole New Engineer" by David E. Goldberg and Mark Sommerville outlines the experiences of Franklin W. Olin College of Engineering and the iFoundry at the University of Illinois.

The review has been expanded below to include some notable examples of works to improve social competence in engineering since this chapter was published in the journal of Education Sciences in 2022

1. **Emotional Intelligence Training**

Authors from Lawrence Technological University studied the effects of an interdisciplinary service-learning engineering design course called "Entrepreneurial Engineering Design Studio" in foster empathy among engineering sophomore-senior level undergraduates. The course integrates design thinking and

service learning. A key feature of the course is a service-learning component executed in partnership with local non-profit organizations aiding individuals with disabilities. Before customer interactions, students participate in an accessibility simulation activity to better comprehend the daily experiences of individuals with disabilities, thereby fostering empathy in design (Morano & Cole, 2024). This paper showed distinctions in levels of emotional intelligence between different cohorts: “results at pre-course found female engineering students had higher EQ compared to males, seniors had higher EQ compared to juniors and sophomores, and biomedical engineering students had higher EQ compared to civil engineering, electrical engineering, industrial engineering, and mechanical engineering students” (Morano & Cole, 2024). The outcome of this study showed that the students exhibited increases in empathy following the course, however they were not statistically significant. The authors of this article cite the paper that this chapter is based on.

2. Bias Identification for Successful Collaborations

Collaboration is central to the profession of engineering and teamwork. A study published in Science and Engineering Ethics described a workshop intended to enable engineering students to work equitably in diverse teams. Key features of this workshop included an environment of emotional safety, opportunities to discuss opinions, and opportunities to practice strategies to address bias and discrimination in teams. The results of the workshop suggest that engineering students found the workshop useful to their professional practice. Follow up studies suggested that the workshop led to behavioural changes in the area of proactive teamwork strategies intended to reduce the impact of unconscious bias (Isaac, Kotlik, & Tormey, 2023).

A study at Pennsylvania State University’s Aerospace engineering department has revised its senior capstone project to enhance diversity, equity, and inclusion (DEI) education. This was done to equip students with actionable strategies for fostering inclusivity and psychological safety in team settings to

improve project outcomes. Early anecdotal evidence is positive. As such a further study will implement pre- and post-module surveys to assess students absorption of DEI concepts.

3. Interdisciplinary Courses Integrating Social Competencies

The article “Humanitarian Engineering: Politics and Practice" by Jenny Peterson and Gabriel Potvin, published in the Proceedings of the Canadian Engineering Education Association (CEEA) 2024 conference details the development and initial outcomes of a novel interdisciplinary course at the University of British Columbia. This course aimed to equip students with the necessary skills to address complex humanitarian challenges by integrating the technical competence of engineering students with social and political considerations. This course brought together engineering and arts students to collaborate on real-world humanitarian projects in partnership with non-governmental organizations (NGOs). This course introduced students to engineering design, humanitarian theory, and critical political analysis through an interdisciplinary lens. Survey responses from the course’s first offering suggested that it provided students with a unique opportunity to apply their skills to a real world challenge while developing their interdisciplinary collaboration. Some students noted that it reshaped their perspective on their professional roles as engineers, highlighting the value of engaging with peers from different backgrounds and epistemologies. This course represents a significant step forward in preparing engineers to be both technically and social competent. Given the success of the course’s first offering, a more deliberate study of learning outcomes is being planned by the researchers (Peterson & Potvin, 2024).

However, despite the growing global discourse on empathy in engineering, some researchers suggest that engineering education in North America remains largely derivative of engineering sciences approaches that emerged during the 1950’s. (Goldberg, Somerville, & Whitney, 2014).

1.6.6 A Brief Look at the European Context

A brief survey of a 2018 study from five countries in Europe was conducted to determine broad similarities and differences between the North American and European Contexts. Based on research in five European countries (Spain, Italy, Sweden, France and Hungary), this paper "detailed the understanding, requirements and perceived skill gaps of companies hiring engineering graduates, a first step towards improved and assessable global competence education for engineering students" (Ortiz-Marcos, et al., 2020). In this study, 10 of the engineering companies that were interviewed identified social competencies as missing in recently graduated engineers. Social competencies broadly were among the "most relevant global competencies" identified in these five countries. These included competencies such as: communication, teamwork, cooperation, and problem solving; attitudes such as: empathy, flexibility, openness, and adaptability; and personal traits such as: leadership, initiative, sociability, acceptance of differences, and openness.

It is interesting to note that empathy specifically was mentioned as an important attitude in three out of the five European countries.

The engineering firms from these countries also indicated the competencies they felt were missing in new engineering graduates. These included: flexibility, sociability, personal awareness, emotional intelligence, and empathy (Ortiz-Marcos, et al., 2020).

This glance at the missing competencies of engineering graduates as identified by engineering firms in these five countries may imply that many of the same deficiencies in engineering education seem to be present in the European context. This warrants a further comparison between engineering education in North America and of Europe. This is outside of the scope of this dissertation.

The European Network for Accreditation of Engineering Education defines engineering design as:

"…the systematic process of conceiving and developing materials, components, systems and processes to serve useful purposes. Design may be procedural, creative or open-ended and requires application of engineering sciences, working under constraints, and taking into account economic, health and safety, social and environmental factors, codes of practice and applicable laws" (ENAEE, 2022).

In Canada, the Canadian Engineering Accreditation Board defines it as:

"…the process of making informed, thoughtful and creative decisions in devising a product, system, component, or process to meet specified needs. It is an open-ended and generative activity often iterative and multidisciplinary in which natural science, mathematics, and engineering science are incorporated into solutions that satisfy defined objectives within identified requirements and constraints. Typically, the constraints include economic, health and safety, environmental, societal, cultural, and regulatory aspects" (Engineers Canada, 2019).

It is interesting to note that both definitions include social factors and the Canadian definition includes cultural aspects. The definitions also note the need to understand how engineering designs integrate within larger systems. The results from the literature review suggests that while this is the intent of engineering education, there is additional progress to be made in the development of the social competencies required to fully appreciate these connections. The similarities in the educational deficiencies between these two contexts may stem from the way in which governing accreditation bodies define "engineering design", which may direct pedagogical approaches.

1.7 Recommendations for future interventions

The literature suggests a misalignment between the type of design that engineers are being taught during their education, and the type of design that engineers are using to address wicked problems, leaving engineering education "fundamentally misaligned with the times" (Goldberg, Somerville, &

Whitney, 2014). These two types of design (engineering design vs design thinking) will be contrasted in-depth in a future paper. Rittel and Webber noted the "modification of school curricula" explicitly in their examples of wicked problems (Rittel & Webber, 1973). Modifying school curricula to more fully integrate empathy and social competencies into engineering education is itself a wicked problem. This issue could be addressed through an action research approach, which is widely used by educators to "address areas of concern or redress" (Hine, 2013). Action research is conducted by practitioners inside a social context who regard themselves as researchers. Because action research is always undertaken by practitioners within a specific social context, it is considered "insider" research (as opposed to outsider research), which means that the researcher will inevitably influence what is happening (McNiff, Lomax, & Whitehead, 2004). McNiff *et al.* describe how action research involves questioning at several levels – often called first, second, and third order learning (McNiff, Lomax, & Whitehead, 2004). For example, first order learning refers to learning about a situation (McNiff, Lomax, & Whitehead, 2004) - "How is empathic thinking perceived in the culture engineering?". This question has been explored by a small number of previous researchers and is presented in this paper. Second order learning is learning to question what has been learned (McNiff, Lomax, & Whitehead, 2004): "If empathy is devalued within the profession, how might we involve more empathic thinking in engineering to address this gap?". Third order learning is learning to ask why the situation exists as it does, and why it is important to shift the way one contextualizes the situation (McNiff, Lomax, & Whitehead, 2004)- "Why is it important to consider the impact of devaluing empathic abilities within engineering education in the first place?". This situation now requires second and third order thinking to produce a fundamental shift in the way the engineering design education is delivered.

In addition to supporting the integration of social competencies into engineering education, future interventions should also focus on supporting students through any cognitive dissonance that may arise. As described above, the students may be experiencing cognitive dissonance (when actions are

inconsistent with thoughts, beliefs, or attitudes) when their self-schemas of what it means to be an engineer are challenged through courses that stray outside of their expectations.

Engineering educators have a significant influence on the cultural elements, narratives, and epistemological assumptions of engineering students (Walther J. , Brewer, Sochacka, & Miller , 2019). As such, the locus of the change in action research should center on one's own pedagogical approaches within engineering education that are influential in the creation of students' professional identification.

1.8 Chapter Summary

The selected body of literature, while narrow in scope, offers valuable insights into prevailing trends, attitudes, and interventions related to empathy and social competence published in the engineering literature. There was consistency across the themes of the multiple sources identified as discussed in the results section of this chapter. This literature review's emphasis on both conceptualizations of empathy and interventions to improve empathy and social competence provide a reasonable overview of the contextual landscape in the literature. It offers novel insights into the challenge and design of future interventions and achieves its research objectives.

Great progress towards addressing this gap in the training of engineers is being made by many researchers. This dissertation aims to build on this growing body of research and knowledge to offer another incremental step towards addressing this noted gap in the training of engineers.

This chapter analyzed and synthesized available literature from the North American context on empathy in engineering that: 1) explicitly discussed the conceptualization of empathy in engineering education or practice, 2) discussed how engineering education changes student engagement with issues of social responsibility, and 3) described the implementation of interventions intended to increase social competencies. Through this exercise, five themes for engineers' conceptualizations of empathy in

education and practiced emerged: 1) a solid theoretical conceptualization of empathy, 2) a utilitarian view of empathy, 3) a belief that engineering is inherently empathetic, 4 A recognition of the importance of empathy but an inconsistent approach in teaching it as a core competency of engineers, and 5) a tendency to devalue empathy despite a recognition of its usefulness.

The literature suggests that engineering education focuses heavily on the development of technical competencies and additional progress can be made into the training of social competencies such as empathy. It is suggested that as a result of the active or passive devaluation of social competencies in engineering, students exclude these concepts from their professional identities as engineers. The engineering science model of engineering design education that is taught throughout North America is leaving students ill-equipped to address the wicked problems that the engineers face in the 21st century. Engineering practitioners have stated that empathy and social competencies being integrated into the engineering curriculum have the potential to improve the profession along multiple facets and better equip students for the realities of professional practice. It is interesting to note a brief review of the European context suggested these challenges are also present in the European context.

The literature noted some instances where interventions that attempted to improve empathy in engineering had an opposite effect. It was hypothesized in this paper that these interventions may have challenged students' self-schemas of what it means to be an engineer, leading to cognitive dissonance and a rejection of the concept. From this abduction, it was hypothesized that future interventions to improve social competencies in engineering education must also attend to the students developing professional identities.

This is itself a wicked problem and should be addressed through a design approach equipped to handle complex social systems such as design thinking, systems thinking, and action research. Before future interventions are employed, additional work is needed to identify the best pedagogical approaches in

the literature to support engineering identity formation. From this a framework for integrating social competencies into engineering education can be created. In addition, most of the literature on this subject is qualitative in nature. In order to determine the success of future interventions, a reliable quantitative tool for measuring empathy (and social competencies more broadly) should be used.

Chapter 2: Reframing Engineering Design: Methods from Design Thinking and Systems Thinking to Address Wicked Problems in Engineering Education and Practice

The content in this chapter is published in the following publication: Wilson, E., Dunne, D., Bergen, T., & Mukhopadhyaya, P. (2024). Reframing engineering design: integrating design thinking and systems thinking in engineering education and practice to address wicked problems. Canadian Journal of Civil Engineering, 1 - 14 dx.doi.org/10.1139/cjce-2023-0433.

2.1 Abstract

The conceptualization of "engineering design", as outlined by the Canadian Engineering Accreditation Board (CEAB), has shifted over the years, however, a gap in engineering education remains in the development of non-technical competencies (such as empathy). Design thinking and systems thinking frameworks offer a robust methodology for tackling complex, dynamic, and interconnected challenges—referred to as "wicked problems". By integrating these approaches into the foundation of engineering design education, there may be an avenue to equip engineers with the skills needed to empathize with stakeholders, understand contextual landscapes and generate meaningful solutions that contribute positively to society.

2.2 Introduction

This chapter is based on the second installment in a three-paper series intended to explore how more empathetic design practices can be integrated into engineering education and practice. Based on the findings of an in-depth literature review (Chapter 1) by the authors published in 2022, the challenge is that engineering education does not adequately train engineering students with the empathetic tools, mindsets, and social competencies required to address these wicked problems (Wilson & Mukhopadhyaya, 2022). They are unprepared when a holistic and empathetic approach is of vital

importance. The literature suggests that engineering education focuses heavily on the development of technical competencies at the expense of social competencies such as empathy (Wilson & Mukhopadhyaya, 2022).

This chapter will explore the definitions of engineering design to address the question: “What can be done to address this gap and provide students with the opportunity to acquire the empathetic skills required to appropriately engage with wicked problems?”.

Previous research has shown that some interventions intended to improve empathy and social competence in engineering students have had the opposite effect (Patterson, 2019) (Walther J. , Brewer, Sochacka, & Miller , 2019) (Cech, 2014).

It could be that the activities or instructors were not effective in creating the intended change. Or perhaps this points to a passive devaluation of social competencies in engineering. Some authors in the published literature point to an overarching educational and professional culture that actively or passively devalues these skills. As such, interventions intended to improve these capacities were challenging students’ notions of what it means to be an engineer. The notion of empathy in engineering may have been creating an identity crisis that led to the rejection of the concepts being taught (Wilson & Mukhopadhyaya, 2022).

Therefore, future interventions to improve social competencies and empathy must also attend to the students developing professional identities.

2.3 Defining Engineering Design

In the book, “A Whole New Engineer”, Goldberg et al. describe an era of “rockstar” engineers – innovators and social change makers that challenged the public’s perceptions of possible and impossible, balancing on the cutting edge of social and technological change (Goldberg, Somerville, &

Whitney, 2014). In the decades following the establishment of the Society for the Promotion of Engineering Education in 1894 came the era of automobiles, airplanes, continental railroads, highways, and telephones.

This romantic period of engineering began its decline in the post-World-War I era and continued with the 1955 “Grinter Report”, commissioned by the American Society of Engineering Education (formerly the Society for the Promotion of Engineering Education). This report recommended two tracks for engineering education in North America: the first was heavy on math, physics, and basic sciences and was intended to prepare students for graduate school (Goldberg, Somerville, & Whitney, 2014). The second was intended to prepare graduates for professional practice by focusing on engineering analysis and design. In the end the first track overshadowed the second and led to the engineering science approach being widely adopted (Goldberg, Somerville, & Whitney, 2014).

The resulting engineering graduates from this style of engineering education have been perceived by industry to be “unable to participate” in the engineering problems faced by engineering professionals (Dym, Agogino, Eris, Frey, & Leifer, 2005). As such, modern engineering education is very effective at producing engineering scientists, but not effective at producing engineering designers. The academic literature is clear that traditional approaches to engineering design that are taught within the context of engineering education are not preparing future engineers to design solutions to address wicked problems.

Thompson *et al* showed quantitative deficits in empathy and social skills in those who study physical sciences (including engineering) when compared to those in social and life sciences (Thomson, Wurtzburg, & Centifanti, 2015). Higher levels of empathy predicted membership in social sciences and lower levels of empathy predicted enrolment in physical sciences. This suggests that the deficit in empathy and social skills within the learning environment of physical sciences actually draws individuals

who favour analytic thinking modes and objectivity. An interesting observation they found in the literature was that women majoring in science have a higher rate of switching their subject major within the first year when compared to men. However, their research also provided strong evidence that a disposition towards empathy, not biological gender, was a better predictor of subject major. This suggests that the learning environment of engineering is – in a sense- "weeding out" empathic thinkers (who happen to be primarily women). As this occurs within the first year, it is reasonable to conclude that this deficiency is prevalent across all disciplines of physical sciences. As such, the first year is a critical time to introduce empathic competencies as a pillar of the professional engineering identity before students receive messages to the contrary. Based on this research, it is likely that by 4th year, many of the empathic thinkers that started in engineering have switched into more empathic fields. Those that remain are likely to identify with engineering *because* of its emphasis on the technical competencies.

2.3.1 CEAB Definitions of Engineering Design

To identify the gaps in engineering design education, it is important to understand its current conceptualization by the engineering accreditation boards, which shape the way it is taught in institutions. Until recently there were two definitions of Engineering Design used by the Canadian Engineering Accreditation Board to be used in accreditation criteria:

CEAB Criterion 3.1.4 defined "Design" as "An ability to design solutions for complex, open-ended engineering problems and to design systems, components or processes that meet specified needs with appropriate attention to health and safety risks, applicable standards, and economic, environmental, cultural and societal considerations." (Engineers Canada, 2020)

CEAB Criterion 3.4.4.5 defined "Engineering Design" as follows: "Engineering design integrates mathematics, natural sciences, engineering sciences, and complementary studies in order to develop elements, systems, and processes to meet specific needs. It is a creative, iterative, and open-ended process, subject to constraints which may be governed by standards or legislation to varying degrees depending upon the discipline. These constraints may also relate to economic, health, safety, environmental, societal or other interdisciplinary factors." (Engineers Canada, 2020).

It will be useful to analyze these definitions for their component factors and synthesize them into Table 1. This table shows how the definition of engineering design has shifted since 2002. Although the definition proposed by the Engineering Design Taskforce in 2019 was not adopted, it is still relevant as it shows some of the thought processes behind the shifting definitions.

Table 2 - Comparative Table of Definitions of Engineering Design

	2002 Definition	**Proposed 2019 Definition**	**Adopted 2022 Definition**
Adjectives of design	Creative Iterative Open-ended	Informed Thoughtful Creative Needs based Open-ended Generative Iterative Multidisciplinary	Informed Creative Complex Open-ended Iterative Multi-disciplinary
What is being designed	Systems Components Processes Elements	Product System Component Process	Product System Component Process
Tools of design	Mathematics Natural Science Engineering Science Complementary studies	Natural Science Mathematics Engineering Science	Engineering analysis and judgement Natural Science Mathematics Engineering Science Systematic and current best practices
Objectives of design	Meet specified needs To satisfy defined objectives within requirements and constraints	Produce solutions to satisfy defined objectives within requirements and constraints	Meet specified goals based on engineering analysis and judgement satisfy defined objectives within identified requirements, criteria and constraints

Constraints of design	Appropriate attention to health and safety risks, applicable standards, and economic, environmental, cultural and societal considerations and interdisciplinary factors legislation to varying degrees depending upon the discipline.	economic, health and safety, environmental, societal, cultural, and regulatory aspects	health and safety, sustainability, environmental, ethical, security, economic, aesthetics and human factors, feasibility and compliance with regulatory aspects, universal design issues such as societal, cultural and diversification facets.

In the winter of 2018, the CEAB established the Engineering Design Task Force. It was implemented to address the issues stemming from having two functional definitions of engineering design (Engineers Canada, 2020). The goal was to have one single, accurate and comprehensive definition and interpretive statement on “Engineering Design”.

In 2019, the Task Force produced the Engineering Design Task Force Report, which proposed the following definition of design to CEAB members, intended to replace the two definitions noted above.

> *Engineering design is the process of making informed, thoughtful and creative decisions in devising a product, system, component, or process to meet specified needs. It is an open-ended and generative activity often iterative and multidisciplinary in which natural science, mathematics, and engineering science are incorporated into solutions that satisfy defined objectives within identified requirements and constraints. Typically, the constraints include economic, health and safety, environmental, societal, cultural, and regulatory aspects.*
> (Engineers Canada, 2019)

Between October 1, 2020 and December 4, 2020, the Engineers Canada “Engineering Design Task Force” consulted with stakeholders on the proposed new definition for engineering design to be used in Canadian Engineering Accreditation Board (CEAB) accreditation criteria. The Task Force recommended that CEAB adopt the following definition and interpretive statement to be used in CEAB accreditation criteria. In 2022, CEAB amended its definition of Engineering Design based on the work of the Task Force.

Definition:

> *Engineering design is a process of making informed decisions to creatively devise products, systems, components, or processes to meet specified goals based on engineering analysis and judgement. The process is often characterized as complex, open-ended, iterative, and*

multidisciplinary. Solutions incorporate natural sciences, mathematics, and engineering science, using systematic and current best practices to satisfy defined objectives within identified requirements, criteria and constraints. Constraints to be considered may include (but are not limited to): health and safety, sustainability, environmental, ethical, security, economic, aesthetics and human factors, feasibility and compliance with regulatory aspects, along with universal design issues such as societal, cultural and diversification facets. (Engineers Canada, 2022)

CEAB Interpretive Statement on Engineering Design:

It is recognized that the process, skills, and competencies associated with design are fundamental to the practice of engineering. A key feature of good engineering design education is the instilling of a mindset of creative exploration of a range of approaches to problems framed as complex, open-ended, iterative, and multidisciplinary. The process of making decisions in engineering design requires the use of well-founded skills, competencies and knowledge.

Design education relates to the development of students who approach the design process with goals related to exploring the range of possibilities to meet objectives as set out in problems they face. Design engineers will consider sets of constraints, engineering, computational and scientific tools that can be brought to bear, and the requirements of the problem in arriving at solutions. These solutions are evaluated for their fit in meeting the objectives and also, but of no less importance, their societal, economic, health and safety, as well as regulatory factors as appropriate. (Engineers Canada, 2020)

The CEAB report describes the key elements of the engineering design process. Design at all points in an accredited engineering program, from introductory to advanced, follows this process or some variation (Engineers Canada, 2020).

1. Establishment of needs and description of scope in consideration of project stakeholders.
2. Definition of objectives and criteria, including goals, constraints, and available resources.
3. Identification of universal design needs.
4. Synthesis, including evaluation of alternatives and descriptions of tools and techniques.
5. Analysis.
6. Execution, including computation, prototyping, modelling, and/or implementation.
7. Validation and testing, including acceptance and evaluation.
8. Reporting, including descriptions of the methods and processes applied to the design activity.
9. Recommendations, and statements on the limitations and constraints.

The official and proposed definitions of design since 2002 have all highlighted that design is an iterative, creative, and multidisciplinary process that includes social and cultural considerations. The process above, although shown as a linear process, is in fact meant to be iterative. The revised definitions of design and interpretive statement further highlight that the design mindset is *"creative exploration of a range of approaches to problems framed as complex, open-ended, iterative, and multidisciplinary".* The amended definition in 2022 and the mere existence of the Engineering Design Taskforce shows that there has been a concerted effort to improve design competencies in engineering since 2002, shifting towards greater recognition of complex social, cultural, and human dimensions of engineering design.

Although the adjectives used to describe engineering design have changed over the years (as shown above), the definition has remained similar. The "Tools of Design" have remained largely constant other than the removal of "complementary studies". According to the NSERC Design Chairs in 2004,

“complementary studies” referred to the competencies associated with the “central issues, methodologies, and thought processes of the humanities and social scientists”, “communication skills”, and an “understanding of environmental, cultural, economic, and social impacts of engineering on society and the concept of sustainable development” (Angeles, et al., 2004), a factor of critical importance when addressing wicked problems.

It should be noted that although the revised definitions of engineering design do not explicitly mention “complimentary studies” as defined above, the abilities gained through the complementary studies are mentioned in the “graduate attributes” and are still a requirement for accredited programs. The definition of the skills gained from complimentary studies are explicitly stated within the definitions of graduate attributes. Specifically, items 6, 7, 8, 9, 10. Graduate attributes include:

1. A knowledge base for engineering
2. Problem Analysis
3. Investigation
4. Design
5. Use of engineering tools
6. Individual and teamwork
7. Communication skills
8. Professionalism
9. Impact of engineering on society and environment
10. Ethics and equity
11. Economics and project management
12. Life-long learning

Also, noting that the constraints of engineering design have remained relatively constant, and include elements such as human factors, cultural and societal considerations, and the environment, it is important to continue to include tools in the definition of design that enable design engineers to understand these factors. Simplistic systems are no longer the norm in engineering design (Hernandez, 2018). The problems that engineers face in the 21st century are inescapably both social and technical (Walther, Miller, & Sochacka, 2017).

Although the CEAB definitions of engineering design highlight that it is complex, iterative, and multidisciplinary, a gap remains between these high-level descriptions and how engineering is actually taught and practiced. While the definitions include many of the concepts and criteria that make a problem "wicked" (such as health and safety, sustainability, environmental, ethical, security, economic, aesthetics and human factors, culture etc.), engineering design has not adopted the epistemological frameworks required to address such complexity in a meaningful way. Wicked Problems demand a very different approach than traditional engineering offers in order to produce meaningful solutions (Dorst, 2015).

Accreditation language alone does not ensure that the frameworks and practices needed to address wicked problems are taught. This chapter argues that the fulfill the intent of CEAB's broad definition of engineering design requires curriculum level interventions. The challenge is not then with the definition of design, but how it is operationalized and integrated into the classroom environment.

If engineers are expected to play a role in addressing these issues, they must be trained not only in a deep understanding of technical competencies, but also with the practical skills to actually understand the expansive definition of "human factors" (such as cultural and historical context). Without such an understanding, the engineering designs can have disastrous down-stream consequences as highlighted in the story at the beginning of this dissertation.

The consensus from the literature is that engineering students need greater training in non-technical competencies (Brewer, Sochacka, Walther, & Miller, 2017) such as empathy, communication, creativity, innovation, and systems thinking. This is more acute in some disciplines than others. From the literature reviewed, it seems that during their formal training, engineers are also not widely introduced to the concepts of metacognition, identification of bias, or the other means of logical inference outside of deduction. Once students are studying engineering, there is an emphasis on the development of technical capacities at the exclusion of other intelligences (Goldberg, Somerville, & Whitney, 2014).

There is, however, an approach to design that when combined with the technical training offered by engineering education that may produce engineers with the capacities to address wicked problems, align the training of engineering design with the CEAB definitions of engineering design, and improve professional practice. In the search for a new way to address these open, complex, dynamic, and networked challenges, different fields and sectors are turning to a process of "design thinking" (Dorst, 2015) and "systems thinking" (Morganelli, 2020) (Pourdehnad, Wexler, & Wilson, 2011).

2.4 Design Thinking, and Systems Thinking

Design thinking is a problem-solving approach that emphasizes empathy, abductive reasoning, and rapid iteration to find solutions to complex "wicked" problems (Kolko J. , 2012). Design thinkers use an iterative process of empathy-based problem framing, rigorous qualitative inquiry (ensuring saturation, representation, and triangulation) and abductive reasoning, and low-stakes rapid prototyping.

Systems thinking is an approach to understanding and analyzing complex systems and their interactions. It involves considering the relationships between different components of a system and how they affect one another, rather than focusing on individual parts in isolation. Systems thinking replaces reductionism – reducing a problem down to individual component parts, with expansionism –

understanding that the component parts of a system interact and contribute to one another. (Pourdehnad, Wexler, & Wilson, 2011). In addition, a systems thinking approach puts stakeholders in the "driver's seat". Stakeholders are the designers. They generate ideas and implement concepts. (Pourdehnad, Wexler, & Wilson, 2011).

Design thinking and systems thinking complement one another in innovation frameworks to explore the complex domain of social problems. An innovation framework helps a design team to uncover, co-develop and test out possible solutions or approaches that can help address and transform the conditions that are giving rise to the problem at hand.

There are different interpretations and versions of the design thinking process: IDEO, the world's largest design company, describes the process as three overlapping phases: Inspiration, Ideation, and Implementation (IDEO.org, 2015). The "Luma Institute" describes three key design skills: "Looking, Understanding, and Making" (LUMA Institute, 2023). Vijay Kumar describes it in his book 101 Design Methods as seven distinct modes (tools and mindsets): sense intent, know context, know people, frame insights, explore concepts, frame solutions, and realize offerings (Kumar, 2012). The Stanford "d.school" defines the process as: empathize, define, ideate, prototype, test, and assess (Stanford d.School, 2019). There are a multitude of approaches, however all emphasize how a circular process of qualitative inquiry, abductive reasoning, and hypothesis testing are used to build empathy, frame and re-frame problems, and generate insights that lead to novel solutions to complex issues. Table 3 is synthesis of four methods and the overlap of the purpose of each "phase".

Table 3 - Comparison of Design Thinking Frameworks

IDEO	**LUMA Institute**	**101 Design Methods**	**"d.School"**	**Purpose**
Inspiration	Looking	Sense intent; Know context; Know people;	Empathize	• Building empathy - Understanding people and context.

				• Understanding personal bias.
Ideation	Understanding	Frame insights; Explore concepts;	Define; Ideate;	• Framing the challenge • Analyzing and Synthesizing data to find themes and insights • Exploring potential solutions with low-fidelity prototypes
Implementation	Making	Frame Solutions; Realize Offerings	Prototype; Test; Assess	• Continue to test potential solutions with refined prototypes and user feedback. • Combine promising solutions into "Systems Innovations" • Develop a strategy "roadmap" – how will the solutions be scaled.

2.5 Realigning Engineering Design with Current Design Challenges

The 2022 CEAB definition and interpretive statement on design include mention of the complex, open-ended problems engineers face in practice. It also mentions the approach to producing effective solutions must include iteration, human factors, creative mindsets, and engineering tools. The challenge that remains is providing students with the necessary tools and mindsets to address the social factors of these complex challenges.

The innovation frameworks discussed above would help to align the CEAB definition of "engineering design" with the developing skillsets of engineering designers to address the complex, open ended challenges that engineers face in practice. The remainder of this paper will highlight specific epistemologies from design thinking and systems thinking that could be adopted by instructors of engineering design courses to prepare students for wicked problems, namely:

1. Highlight the importance of problem framing

Appropriate problem framing as defined in the innovation frameworks described above will help engineering designers to build empathy and a deep understanding of the context of a design challenge.

2. Include qualitative inquiry

Qualitative inquiry is a path to empathy development that will help engineers to understand the fundamental nature of the challenge they are aiming to address.

3. Include adbductive reasoning

Abductive reasoning is used to make creative leaps from observed phenomena to testable hypotheses. It is necessary for the creation of new knowledge and innovation soultions.

4. Empathsize rapid prototypeing

Rapid prototyping will help engineering designs to explore potential frames, generate insights, gather user feedback, and determine the efficacy of potential solutions.

5. Position solutions in the larger systems dynamics

Systems thinking positions the design within possible cause and effect relationships within a system. The result is a design that does not cause irreparable harm or additional problems to be solved.

2.5.1 Highlight the Importance of Problem Framing

Designers use sense-making, framing, and "re-framing", either explicitly or implicitly, to make meaning out of data through interpretation and modeling (Kolko J. , 2010). As described by Jon Kolko: "A frame is an active perspective that both describes and perceptually changes a given situation" (Kolko J. , 2010). In simple terms, a frame is a way of seeing a situation. According to Kolko, in technical situations it is often

deemed "irrelevant" or "biasing" because it implicitly references a non-objective way of considering a situation or idea (Kolko J. , 2010).

As defined by Kees Dorst, a frame is an “organizational principle or a coherent set of statements that are useful to think with” (Dorst, 2015). Dorst also notes that a frame brings a certain element of bias that steer explorations and perceptions of the process of creation (Dorst, 2015). However, these biases are chosen for their significance and meaning, and they emerge from a true understanding of the perspective of the “Other” – the target audience. A frame is useful for designers as it is shaped through a process of developing understanding of others’ perspectives through acknowledging and challenging personal bias (Schwandt, 1999), “sensemaking” (Klein, Moon, & Hoffman, 2006), abductive reasoning (Kolko J. , 2012), and aggregation of thoughts, experiences and data (Kolko J. , 2010).

Kees Dorst outlines a nine-step frame creation process for creating problem frames for complex, wicked challenges in his 2015 book “Frame Innovation”. He identifies the nine steps as:

1. **Archaeology:** Investigating, in depth, the apparent problem as well as previous attempts at solving it.
2. **Paradox:** Identifying intertwined issues, paradoxes, or deadlocks that make the problem difficult to solve.
3. **Context:** Exploring the practices of the inner circle of key stakeholders involved in the problem situation.
4. **Field:** Determining what assets (cultural, economic, social, and symbolic) are exchanged between all stakeholders who might be connected to the problem.
5. **Themes:** Analyzing and synthesizing data to find patterns that can be distilled into key insights to guide the design process.

6. **Frames:** Identifying themes that are shared across stakeholder groups that provide different ways of looking at the challenge.
7. **Futures:** Testing of problem frames based on low-stakes solution exploration, divergent thinking, and user feedback to determine if the design is heading in the right direction.
8. **Transformation:** Identifying promising directions, convergent thinking, and "weeding out" frames and solutions concepts that are not feasible, viable, or desirable.
9. **Integration:** Making sure that the new frames and solutions they will initiate are well integrated into the broader context of the stakeholders involved.

It could be argued that the above processes are aligned with systems-thinking methodologies in that the choice of frame ultimately leads to a boundary selection of the system model. Choosing a frame yields choices in the selection of which components and their interactions are viewed as "important" within the systemic context of a design challenge.

The development of a "good frame" does not necessarily lead to solutions to a problem. Rather, a "good frame" could lead to the more accurate identification a problem and a solution space that can be reached. That is to say a "good frame" leads to the identification of a co-evolution pathway (Dorst, 2015) . This may seem like a catch-22, however Rittel and Weber state that with wicked problems "finding the problem is thus the same as finding the solution" (Rittel & Webber, 1973). This same phenomenon is noted in social systems design when Herbert Simon states "A paradoxical, but perhaps realistic, view of design goals is that their function is to motivate activity which in turn will generate new goals" (Simon, 1996, p. 162). As Rittel and Webber explain: "the information needed to understand the problem depends upon one's idea for solving it and one cannot understand the problem without knowing about its context; one cannot meaningfully search for information without the orientation of a solution concept; one cannot first understand, then solve" (Rittel & Webber, 1973). In this way an

understanding of the problem is defined in tandem with solutions development and an accurate prediction of system dynamics. This is co-evolution at work and is described further in section 2.5.5 .

A foundational component of creating a problem frame centered in the perspectives of key stakeholders is to have awareness of one's own biases. True understanding "begins from the full acknowledgment that as interpreters we are situated within our own tradition" or personal belief (Schwandt, 1999). It is imperative to be honest and clear with oneself about one's own knowledge and ignorance. Thomas A. Schwandt states that "It is only from such a posture that an interpreter can experience the Other truly as an Other and not overlook his or her claim, but let them really say something to us...Hence, understanding requires an openness to experience, a willingness to engage in a dialogue with that which challenges our self-understanding" (Schwandt, 1999).

To understand is to be vulnerable. It requires the interpreter to expose themselves to the "counterweight" of the Other's contribution (Schwandt, 1999). In doing so, they open themselves to the possibility that a true understanding of the Other's perspective may require them to amend or abandon a long-held belief and create in them a new way to see reality. Real empathy and understanding cannot arise where one clings to one's own beliefs and ways of seeing a situation. It requires openness to a new way of seeing the world and a recognition of One's biases. As a form of sensemaking, it "requires a motivated, continuous effort to understand connections (which can be among people, places, and events) in order to anticipate their trajectories and act effectively" (Klein, Moon, & Hoffman, 2006)

As part of the answer to equipping engineers to address wicked problems, Walther *et. al* propose a re-examination and broadening of the discourse and conceptions around engineers' service to society and suggest that engineering education must focus on the notion of a "whole professional", giving engineers a tangible opportunity to integrate personal values and beliefs with professional goals and actions. They suggest that engineers must "fundamentally grapple with the contextual and deeply personal question

of what it means to be an engineer in the world" (Walther, Miller, & Sochacka, 2017). Walther *et al* highlight an important step but focusing on the development of the "whole professional" needs to be paired with a focus on metacognition – developing an awareness and understanding of their own thought processes and biases. Engineers must see that their perspective and interpretation of the world is only one of many equally valid realities. This is foundational for properly framing complex wicked problems from stakeholder perspectives using research-based insights.

Highlighting the importance of framing as defined in innovation will lay the important foundations for building empathy and a deep understanding of the context and a design challenge. This will help engineers to produce more meaningful solutions to complex challenges, "framed" and "reframed" in the needs of the systems actors most impacted by the design challenge.

2.5.2 Include Qualitative Inquiry as a Path to Empathy Building

Discussed above, a frame is produced through an iterative process of exploration and "reframing" based on data-based insights. The methods used to gain an empathetic understanding of the people and context of a challenge is through qualitative inquiry. Empathy is key to understanding the people and their context within the system.

The epistemologies of engineering science generally lie in quantitative approaches to support or negate hypotheses (Hernandez, 2018). Quantitative approaches use deductive reasoning to find what is factually true from data through the application of generalized theory. It assumes a fixed and measurable reality (Minichiello & Kottler, 2010).

The following table, adapted from Minichiello & Kottler, 2010, contrasts the difference between qualitative and quantitative research.

Table 4 - Key Characteristics of Qualitative and Quantitative Research

	Qualitative	**Quantitative**
Philosophy	Interpretivism	Positivism
Assumptions	Dynamic, negotiated reality	Fixed reality
Reasoning	Circular, Inductive process going from specific to general, Abductive (forming hypotheses)	Deductive (applying generalized theory to find what is true)
Research Strategy	Observations, interviews, ethnographies,	Measurement using instruments, conducting experiments
Participant role	Active informants about their experience, perceptions, and interpretation of reality, co-creators of hypotheses	Subjects of experimentation to validate or negate hypotheses
Process	Emergent, flexible	Fixed, explicitly stated in advance
Validity	Establishing through triangulation, saturation, representation	Established through statistical methods
Outcomes	explore novel ideas in areas where phenomena are poorly understood, describe human experience in rich detail, discover new ways of understanding people and context, and develop new theories to account for phenomena	find what is factually true from data through the application of generalized theory.

Note: This table has been adapted from (Minichiello & Kottler, 2010)

In contrast to the typical approaches to engineering design, Innovation frameworks rely heavily on qualitative research to explore novel areas in phenomena that are poorly understood, describe human experience in detailed and meaningful ways, discover new ways of understanding the world and its inhabitants, and develop new theories (Minichiello & Kottler, 2010).

Whereas quantitative researchers are required to stick to an explicitly pre-defined research protocol, qualitative researchers are “masters of improvisation and thinking on their feet” (Minichiello & Kottler, 2010) – adjusting protocol to fit the unique requirements of every situation and context. Depending on how participants are responding, the inquiry will continually evolve and even change the fundamental nature of your research question (Minichiello & Kottler, 2010). This is known as “reframing” the problem.

Framing is done in an iterative manner as qualitative inquiry reveals hidden insights about the nature of the problem. As the designer gains a deeper understanding of the Other's perspectives and makes sense of data, the challenge is reframed to better align solutions concepts to user needs.

There is a widespread and growing recognition of the importance for designers to gain empathy with the users for whom they are designing (Kouprie & Sleeswijk Visser, 2009). Kouprie *et al* from TU Delft in the Netherlands present a framework to the design community on the application of empathy as it has been developed in psychology. They suggest that empathy has four phases: discovery, immersion, connection, and detachment. They stress the importance of empathy building in design and suggest that it is a process that cannot be rushed and must be allowed time to develop in order to be effective.

In the "discovery" phase the designer approaches the user and becomes curious and motivated to explore the user's context. This phase cannot be achieved sufficiently if the designer is not intrinsically motivated to understand the user. It cannot be forced.

In the "immersion" phase the designer takes an active role by "stepping into" and experiencing the user's world. The designer is surprised by various aspects that influence the user's lived experience. In thisphase it is important that the designer absorb information without judgement.

In the connection phase the designer explicitly recalls his or her own memories and experiences in order to create understanding. The intent is to make an emotional connection and resonate with the user's experience.

In the "detachment" phase, the designer detaches from his or her emotional connection and "steps out" of the user's world to reflect and deploy new insights for ideation (Kouprie & Sleeswijk Visser, 2009).

Qualitative inquiry is a path to empathy development that will help engineers to understand the perspectives of people and key stakeholders within a system. This is an important part of identifying the

fundamental nature of a design challenge. Qualitative inquiry will enable engineers to gain a deep understanding of the context in which the challenge is situated.

2.5.3 Include Abductive Reasoning as a Path to Insight and Solution Development

As discussed, wicked problems require an iterative and emergent process that implements abductive reasoning. Innovation frameworks draw on abductive reasoning to make creative leaps from incomplete observations to a hypothesis that explains the observation (Carson, 2008). Simply put, abduction is about making an educated guess to come up with the most likely explanation of a phenomena based on an incomplete set of observations (or data set). Inductive reasoning moves from observations to generalizations based on what is probable. Deductive reasoning moves from a general premise to a specific conclusion (think of solving for X in an algebraic equation). Each form of logical inference serves different purposes and has its strengths and limitations.

Qualitative inquiry and abductive reasoning are used to form insights, hypotheses, and problem frames for further testing and exploration based on user feedback. It aims to discover new design variables, or to re-examine design variables that the engineer had previously considered as unimportant to the problem (Hernandez, 2018). Abductive reasoning is the path to the creation of new knowledge.

Many of the typical problems engineers are taught to address through an engineering science approach during their education can be solved through a process of deduction, applied in a predictable way, to produce a verifiably “true” result. This approach will produce solutions for “tame” problems (well-defined problems with a verifiably true result) (Rittel & Webber, 1973). In contrast to a “wicked problem” (one that is ill-defined, complex, and interconnected) (Rittel & Webber, 1973). For a tame

problem "an exhaustive formulation can be stated containing all the information the problem-solver needs for understanding and solving the problem" (Rittel & Webber, 1973).

But "tame problems" are not the only type of problems that most practicing engineers are addressing. Training engineers in abductive reasoning may help them to produce innovative frames to wicked design challenges based on the analysis of datasets produced through qualitative inquiry.

2.5.4 Emphasize Rapid Prototyping as a Means to Understanding the Design Challenge

A study by Jensen et al concluded that there are five main interpretations of prototyping in engineering design. Much of the interpretations of prototypes from the body of literature studied indicates it is often seen as a means of validating technical feasibility and functionality and converging and refining on solutions concepts. Not as a means of identifying or framing the problem. Jensen et al describe that, in their study, prototyping as a means of divergent thinking (further evolution of concepts) was fairly uncommon within their thematic analysis (Jensen, Ozkil, & Mortensen, 2016). This was a view of prototyping which was "opposed to the majority of definitions" (Jensen, Ozkil, & Mortensen, 2016). The concept of prototyping from the perspective of design thinking closely aligns with this interpretation of prototyping as a means of divergent thinking.

Design thinking encourages testing early and often through the use of "rapid prototyping". This is also seen in the "Futures" step of the frame Innovation model proposed by Dorst. Rapid prototypes are rough, low-fidelity solution attempts that are just refined enough to see if a solution is worth further exploration based on user feedback (Dunne, 2018). In design thinking, rapid prototypes are used as a means of concept validation, exploration, iteration, and learning with small groups of participants in a way that does not influence the dynamics of the system at large. Each attempt raises further questions

about the nature, scope, and impact of the problem (Dunne, 2018). For designers, a prototype is a means to generate insights, and generate discussion in the design team. The physical prototype itself is of little value, but the understanding of the problem and the users that these low-fidelity prototypes create is of immense value (Dunne, 2018). Designers use rapid prototypes as critical vehicles for thinking. Making is about understanding problems and solving them at the same time (Dunne, 2018). Kees Dorst warns that designers should not get too attached to any one idea: “design solution ideas are generated only for the purpose of exploration: They should be noted down but not pursued. Investing too much effort into any one idea at this stage might lead to attachment and a premature closing of the problem space while the quality of the frame that lies at the root of the idea is still being evaluated. In these playful explorations, we creatively envision how things might work.” (Dorst, 2015).

To better align engineering design with the practices of design thinking, engineers should integrate a broader understanding of prototyping beyond technical validation. As described above, prototyping can be a means of both convergent and divergent thinking. Prototyping can be a means to explore and understand the nature and scope of the problem itself, with solutions co-evolving with a frame of the problem as is unique in wicked problem solving.

2.5.5 Position Solutions within the Larger System

As mentioned at the beginning of this dissertation, a poorly framed problem and a hastily implemented solution devoid of stakeholder input (the unilateral decision to install a system of culverts) produced cascading consequences within the system that are continuing to impact Tsawout First Nation to this day.

This story illustrates why design solutions must be positioned within the larger context – understanding how stakeholders and the numerous elements in the system interact. Systems thinking considers how the system as a whole works together to create specific outcomes, patterns, and behaviors.

In his book "the Sciences of the Artificial" Herbert A. Simon presents a positivist and pragmatic approach to design for social systems. His approach is algorithmic in nature and finds an analogy in control theory. Simon presents two concepts from control theory – prediction and feedback – and relates them to the design process. Simon states that the quality of design is likely to depend heavily on the quality of the data available (Simon, 1996, p. 146) and that the task is not to design without data, but to incorporate assessment of the quality of the data.

Simon recognizes that "data about the future – predictions – are commonly the weakest points in our armour of fact" (Simon, 1996, p. 147) and are often "hard to come by" (Simon, 1996). In designing for complex social situations, he makes the observation that we can rarely be confident enough in our models to simply extrapolate observations to predict some future state (Simon, 1996). Drawing on an analogy to control systems, Simon warns about the dangers of inaccurate predictions of system dynamics on intended outcomes.

"In domains where some reasonable degree of prediction is possible, a system's adaptation to its environment can usually be improved by combining predictive control with homeostatic and feedback methods. It is well known in control theory, however, that active, feedforward control, using predictions, can throw a system into undamped oscillation unless the control responses are carefully designed to maintain stability. Because of the possible destabilizing effects of taking inaccurate predictive data too seriously, it is sometimes advantageous to omit prediction entirely, relying wholly on feedback, unless the quality of the predictions is high" (Simon, 1996).

A purely feedback approach to design may be an acceptable approach to "tame" problems. Feedback is akin to a trial-and-error approach. The risk in relying on a feedback-based approach to design in complex social systems stems from their classification as "wicked problems". A fundamental trait of wicked problems is that a trial an error approach is unwise, as the designer has "no right to be wrong"

(Buchanan, 1992). In wicked problems (as in predictive control systems), a poor solution hastily implemented can also lead to “undamped oscillation”. That is to say, it can lead to unforeseen and cascading negative consequences.

To expand on Herbert Simon’s control systems analogy for design in social systems (Simon, 1996), design thinking helps to improve the accuracy of prediction. It is used to identify system actors and elements, form hypothesis, insights, and problem frames. Adapting to the emerging patterns and exploring hypotheses through further research helps achieve rigor through triangulation, saturation, and representation. Rigor ensures the problem is accurately framed within the realities of the system as a whole. Rapid prototyping provides a vehicle for the co-evolution of the problem-space and the solution space (Dunne, 2018) and concept validation in low-stakes and isolated scenarios that do not influence large-scale system dynamics.

The result of the implementation of design thinking is an accurate and reliable prediction of system dynamics. A good prediction of future system states removes the bulk of the error between a desired output and an initial condition before the system needs to provide feedback to respond to it. This is called “feed-forward control” or “zero-error” feedback design in control systems. A diagram for this process can be found in Figure 3.

Design Thinking helps to ensure “good” solutions are produced. Systems thinking positions the design within possible cause and effect relationships. The result is a design that remain within acceptable bounds of consequence and does not cause irreparable harm or additional problems, as shown in Figure 4. However, no prediction is perfect, which means that the initial output after the implementation of a solution in a system will not perfectly match the desired outcomes. This is where minor changes based on feedback can guide *small* tweaks to the design order to improve the outcomes.

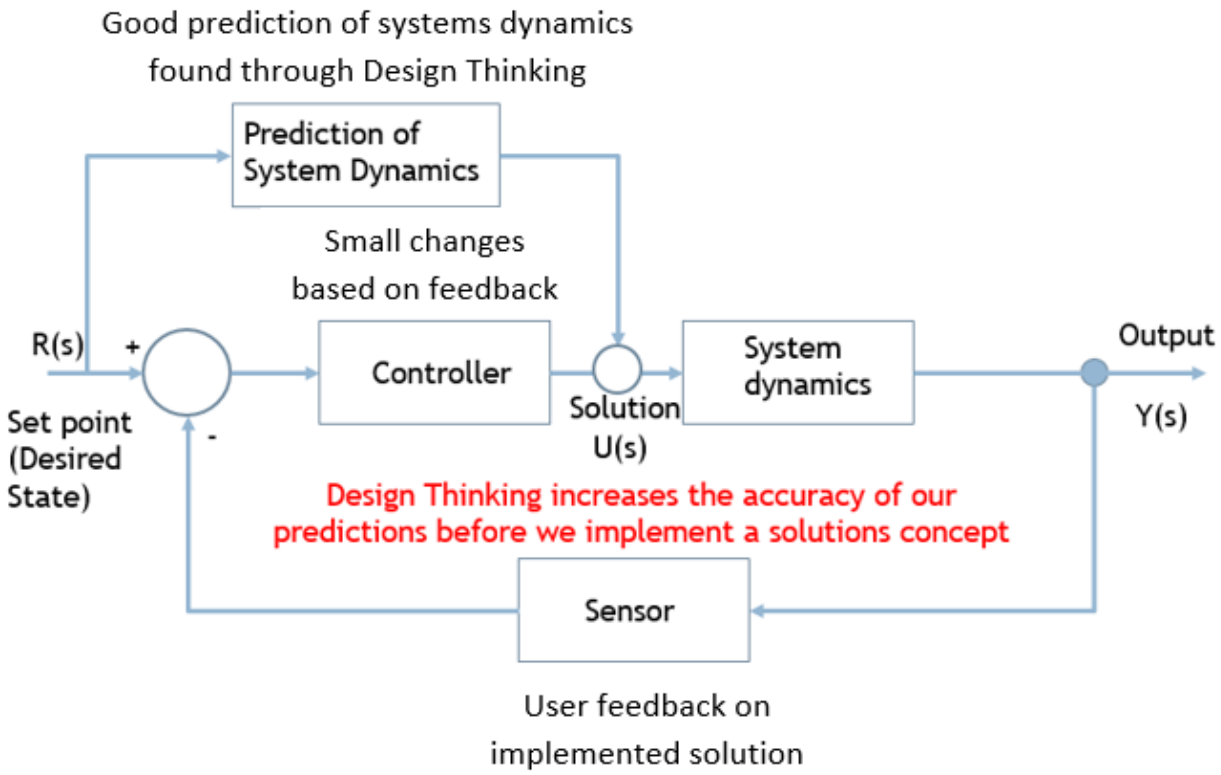


Figure 3 - Control Systems Analogy

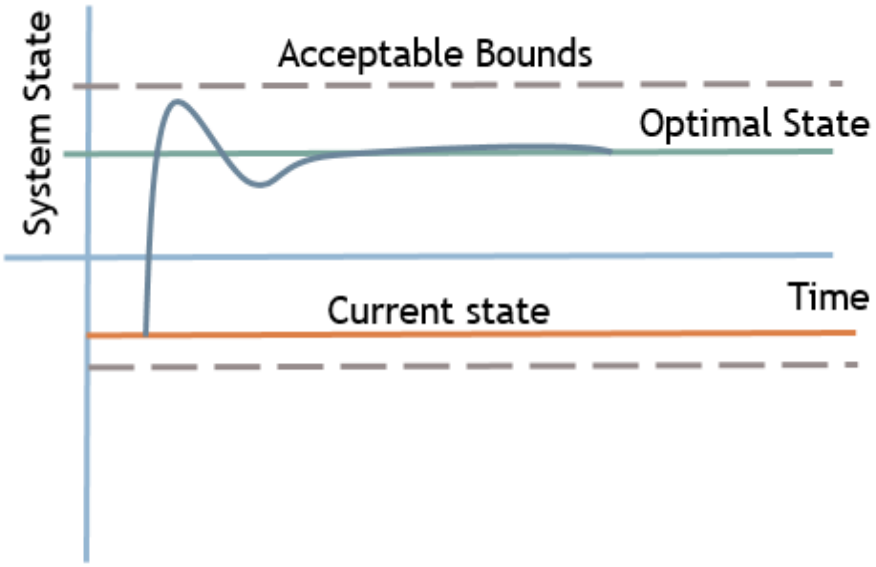


Figure 4 - Acceptable Systems State Diagram

2.5.6 Chapter Summary

Engineers frequently encounter intricate, interconnected challenges at the intersection of both social and technical dimensions. The existing education framework, based largely on the engineering science model of the 1950's falls short in preparing students to the real-world complexities of wicked problems. While there have been revisions in the Canadian Engineering Accreditation Board's definitions of "Engineering Design" to address this issue, there remains a deficiency in developing the non-technical competencies essential for engaging with such complex problems.

This paper presents epistemologies from design thinking and systems thinking that may improve engineering design education and increase the social competencies of engineers. These methodologies, rooted in empathy and understanding interconnections, empower design teams and stakeholders to explore, co-develop, and test solutions to intricate issues at the intersection of technology and society. They emphasize an empathetic and iterative process of problem framing, qualitative inquiry, and hypothesis testing to generate novel solutions.

This paper advocates for the integration of design thinking and systems thinking into the engineering design curriculum in an argument that it may cultivate vital social competencies like empathy and self-awareness, while also proving the tools to address wicked problems. By incorporating these approaches into engineering design education, engineering students may be provided with the tools and mindsets required to understand the contexts and systems in which designs are implemented.

Integrating concepts from design thinking and systems thinking into engineering design courses may provide engineers with the important foundations for building empathy and a deep understanding of the context of a design challenge. This may help engineers to produce more impactful solutions to

complex challenges, “framed” and “reframed” in the needs of the systems actors most impacted by the design challenge, driving innovation in engineering education and practice.

Chapter 3: Emotional Intelligence in Engineering Education: Exploring the Influence of Empathetic Design Approaches in a Fourth-year Engineering Class through a Mixed Methods Approach

The content in this chapter is published in the following publication: Wilson, E., Dunne, D., Bergen, T., & Mukhopadhyaya, P. (2024). - Emotional intelligence in Engineering Education: Exploring the Influence of Empathetic Design Approaches in a Fourth-year Engineering Class. Canadian Journal of Civil Engineering

3.1 Abstract:

This paper explores the impact of integrating design thinking and systems thinking frameworks and methodologies into a participatory learning environment to enhance emotional intelligence (EI) among fourth-year engineering students at the University of Victoria. This study was undertaken in order to address the noted gap in the social competencies of engineering graduates frequently noted in both literature and by engineering practitioners.

A course, "Infrastructure Design with Indigenous Communities," was re-developed, drawing on theories of identity formation and best practices from educational psychology. A mixed methods approach was used to analyze the data. This included pre and post-semester EQi2.0 emotional intelligence inventories, and thematic analysis of qualitative self-reflective writings to triangulate the data. The sample included 30 4th-year civil engineering students. Due to challenges aligning students' schedules with EQi2.0 certified coaches for mandatory debriefing, only 17 students were able to provide their post-semester EQi2.0 inventories before the end of the semester. Therefore the statistical analysis was limited to a sample size of 17.

Statistical analysis of pre and post-semester EQi2.0 emotional intelligence inventories from the 17 students indicated an average overall EI increase of 5.4 points with a critical t-value of 3.105 and a p-value

of 0.0034, rejecting the null hypothesis that the course did not affect the students' EI. Qualitative data and thematic analysis of were used to triangulate the findings to support the hypothesis that the course had a direct impact on the students' EI.

This study is highly relevant to engineering education and practice in general. It highlights and addresses the need for engineers to possess not only technical competencies, but also emotional competencies to address complex, interconnected challenges at the intersection of technology and society. This is especially crucial when working in cross-cultural contexts with Indigenous communities.

This study addresses a gap of relevance to the contemporary training of engineering students. This study suggests that the careful integration of design thinking and systems thinking into engineering curricula increases many trait parameters of emotional intelligence, including empathy. The framework presented in this chapter highlights key themes and activities for developing essential social competencies in engineering. The themes of activities included activities related to: 1) developing social and cultural awareness, 2) building relationships and collaboration, 3) experiential and applied learning, 4) problem-solving and critical thinking, 5) self-reflection and personal growth, and 6) communication and leadership development. This may be beneficial to engineering academia and practices as it produces engineers with more developed social competencies who may be better equipped to consider the social nuances and impacts of engineering designs.

3.2 Introduction

Many of the era-defining challenges that engineers face demand an understanding not only of technical competencies, but also of human behaviour, cultural dynamics, and situational context. These elements are frequently overlooked in engineering curricula. These problems are referred to as “wicked problems”. Wicked problems are a category of social system problems. They are characterized by ill-defined parameters, ambiguous and often contradictory information, multiple stakeholders with divergent or conflicting values, and intricate systemic implications that are challenging to fully understand (Buchanan, 1992) (Rittel & Webber, 1973). Wicked problems demand a very different approach than traditional engineering offers in order to produce meaningful solutions (Dorst, 2015). Engineers should possess a profound comprehension of both technical and non-technical factors to enable them to contextualize solutions within the broader socio-cultural context. Limited comprehension of non-technical factors within complex, interconnected systems can lead to unforeseen negative consequences.

This chapter is based on the third installment in a series of papers exploring the role of empathy in engineering education and practice. However, this chapter broadens the study to “emotional intelligence” (of which empathy is a sub-category) as it more closely aligns with the notion of “social competencies” as highlighted in the literature.

3.2.1 Improving Students’ Emotional intelligence with Design Thinking and Systems Thinking

During the literature review in Chapter 1, it was found that engineering industry indicated the competencies missing in new engineering graduates included: flexibility, sociability, personal awareness, emotional intelligence, and empathy (Ortiz-Marcos, et al., 2020). While the two first chapters studied

empathy in particular, the third paper was expanded to emotional intelligence more broadly as the authors determined it better aligned with the concept of "social competence" of which empathy is one part.

This chapter will provide an in-depth discussion of the aforementioned intervention, a course entitled "Infrastructure Design with Indigenous Communities". This course was re-designed and implemented at the University of Victoria with the goal of increasing the social competencies of fourth-year Civil Engineering Students.

Specifically, the sub-categories of emotional intelligence related to empathy, social responsibility, and self-awareness were targeted, as well as the broader composite categories of self-perception, self-expression, and interpersonal skills.

The context of this course was specifically chosen as Indigenous Nations are at the forefront of many wicked challenges. This is a setting where an empathetic and holistic approach, considerate of culture and history is of vital importance in producing meaningful solutions.

It is vital for engineers working in the context of infrastructure design in Indigenous Nations to understand how historical and present-day legislation has shaped life on reserve. The strangling tendrils of the Indian Act inextricably connect infrastructure challenges to cultural, and environmental challenges – a worthy topic for a dissertation in and of itself.

By engaging with the course material, students were equipped with the necessary historical knowledge, mindsets, and empathetic design tools needed to respectfully engage with Indigenous Nations concerning infrastructure challenges. This was accomplished via a semester-long problem-based learning course where students engaged with real-world design challenges provided by Indigenous Nation partners.

To gauge the impact, students' social competencies were assessed pre-semester and post-semester using an emotional intelligence Inventory – with empathy being one of 15 characteristics that contributed to one's emotional intelligence profile.

This chapter will present an in-depth description of this intervention, as well as the results of the pre-semester and post-semester assessments.

3.3 Methods

The working hypothesis from the previous chapters is that careful integration of design thinking and systems thinking methodologies in a participatory learning environment, while supporting students in developing professional identities will increase emotional intelligence, including empathy. The null hypothesis is that there will be no noticeable change. In 2022 the authors redeveloped a course within the Civil Engineering program at the University of Victoria to explicitly incorporate innovation frameworks into the engineering design curriculum to better prepare students to engage with wicked problems.

As noted above an empathetic and holistic approach is especially important when working with Indigenous Nations where colonial practices and Canada's history of oppression of Indigenous peoples have left painful, lasting legacies, including in the design and delivery of buildings and infrastructure projects. The purpose of this course was to encourage the adoption of empathetic design frameworks into the engineering curriculum to improve the emotional intelligence of the students (specifically empathy, social responsibility, and self-awareness, self-perception, self-expression, and interpersonal skills) .

The literature noted some instances where attempts to integrate empathy into the engineering curriculum were met with resistance by the students (Wilson & Mukhopadhyaya, 2022). It was

hypothesized that this was due to the concepts challenging students' perceptions of what it means to be an engineer, leading to cognitive dissonance and rejection of the concept (Walther J. , Brewer, Sochacka, & Miller , 2019). Therefore, it was noted that future interventions to adopt empathetic design practices into engineering must be done so carefully, considering best practices in educational psychology and pedagogy to support students' developing professional identities.

3.3.1 Course Design

The existing course already had a strong emphasis on understanding historical context when working with Indigenous communities and had some innovative teachings for the students to connect with the history. The course was redesigned in an effort to enhance the strong foundation of the course with frameworks from design and systems thinking aimed at producing good solutions to wicked challenges.

The existing activities in the course included:

- Indigenous cultural acumen training provided by the University of Victoria's First Peoples' House. This training highlighted the history of colonization, residential schools, Indian hospitals, and government policies such as the Indian Act.
- KAIROS Blanket Exercise at the First Peoples House on the University Campus. The KAIROS Blanket Exercise is an experiential activity that highlights the impacts of colonization on Indigenous Nations across Canada. It is facilitated by a KAIROS practitioner.
- Problem based learning on team projects with First Nation partners.
- In class lectures on case studies, policy, and guest presenters.

Re-designed (or re-planned) elements of the course included:

- Projects with First Nation partner communities (new projects are sought each year the course is offered).

- Fieldtrips to partner communities.
    - Clam garden maintenance.
    - Estuary walk with Nation fisheries department biologists.
    - Community tours.
    - Carving facility tour with Master Tla-o-qui-aht carver.
    - Tour of the IPCA Innovation Centre in Clayoquot sound.
- Final project (re-designed based on design and systems thinking methodologies and to scaffold student deliverables)

New elements brought to the course included:

- Design and systems thinking mindsets and tools
    - Design mindset modules (expert vs learner mindsets).
    - Problem framing and reframing.
    - Bias identification modules.
    - Self-reflective writings.
    - Qualitative research planning modules.
    - Qualitative data analysis and synthesis modules.
        - Affinity mapping, coding, and thematic analysis.
    - Ethnographic research strategies such as auto ethnography, interviews.
        - “Tell me about home” practice interview assignment.
    - Problem tree analysis and “ice-berg diagrams” to analyze systemic complexity.
        - Housing complexity problem tree analysis – seeing systemic complexity in on-reserve housing.
- Emotional Intelligence Inventories

    - EQi2.0 training and coaching.
    - Leadership development strategies.
- Attention to the frameworks of identity formation and self-schemas.

In combination with the lessons learned about the conceptualization of empathy in engineering, suggestions from the literature, and best practices in educational psychology and the scholarship of teaching and learning, the following approaches outlined in Table 5 were deliberately integrated into the course to target specific EI composite categories and sub-categories:

Table 5 - Pedagogical Approaches Informing the Course Design

Pedagogical Approach	**Literature References**	**Targeted EI sub-category**
▪ Deliberately model and create an educational environment that promotes empathy.	(Wong K. , et al., 2016) (Walther J. , Brewer, Sochacka, & Miller , 2019) (Bielefeldt & Canney, 2015) (Strobel, Hess, Pan, & Wachter Morris, 2013) (Brewer, Sochacka, Walther, & Miller, 2017) (Goldberg, Somerville, & Whitney, A Whole New Engineer: The Coming Revolution in Engineering Education, 2014)	Empathy
▪ Explicitly address empathy and its place in engineering.	(Walther J. , Brewer, Sochacka, & Miller , 2019) (Strobel, Hess, Pan, & Wachter Morris, 2013)	Empathy
▪ Bring in additional faculty when discussing empathy to highlight its importance.	(Wong K. , et al., 2016)	Empathy
▪ Attend to student's professional identity formation and career aspirations. ▪ Encourage self-reflection.	(Carroll, Wang, & Delaine, 2018) (Fila , et al., 2014) (Walther, Miller, & Sochacka, 2017) (Walther J. , Brewer, Sochacka, & Miller , 2019) (Cech, 2014) (Bielefeldt & Canney,	Self-perception, self-expression, interpersonal, self-awareness

▪ Encourage professional socialization with engineering practitioners. ▪ Encourage students to grapple with what it means to be an engineer.	2015) (Goldberg, Somerville, & Whitney, 2014)	
▪ Encourage intrinsic motivation by connecting to students' interests, promoting self-determination, and incorporating real-world experiences based on community engagement, service learning, and design thinking.	(Ambrose, Bridges, & Lovett, 2010) (Woodock, McDonagh, Magee, Ball, & Iqbal, 2019) (Carroll, Wang, & Delaine, 2018) (Strobel, Hess, Pan, & Wachter Morris, 2013) (Walther, Miller, & Sochacka, 2017) (Fila , et al., 2014) (Rasoal, Danielsson, & Jungert, 2012) (Wong K. , et al., 2016) (Bairaktarova, Bernstein, Reid, & Ramani, 2016) (Hoople & Choi-Fitzpatrick, 2017) (Bielefeldt & Canney, 2015) (Canney & Bielefeldt, 2015)	Self-expression, social responsibility
▪ Encourage teamwork, interdisciplinary engagement and a sense of community.	(Hoople & Choi-Fitzpatrick, 2017) (Fila , et al., 2014) (Wong K. , et al., 2016) (Canney & Bielefeldt, 2015) (Fila , et al., 2014) (Walther, Miller, & Kellam, 2012) (Hoople & Choi-	Interpersonal, empathy

	Fitzpatrick, 2017) (Goldberg, Somerville, & Whitney, 2014)	
▪ Be mindful of the pitfalls and psychological underpinnings around identity formation.	(Pratt, The Good, the Bad, and the Ambivalent: Managing Identification among Amway Distributros, 2000) (Reeve, Understanding Motivation and Emotion 5th Edition, 2009)	
▪ Adopt the role of a coach as the instructor to model empathy, understanding, and the mindset of design.	(Dimopoulous, Bubbar, Gaetz, & Wild, 2017) (Goldberg, Somerville, & Whitney, 2014)	Empathy, self-awareness, self-expression

The redesigned course focused heavily on the tools and mindsets of design thinking and systems thinking as described above – highlighting the importance of empathy-based problem frames, qualitative inquiry, abductive reasoning, and rapid prototyping.

Focusing on the mindsets and toolsets of design thinking and systems thinking explicitly created an environment that openly and deliberately modelled and discussed empathy.

Students were provided with the opportunity to learn interactively through a “studio learning” format. Design thinking and systems thinking methodologies and mindsets were provided through lectures and readings. Lectures and readings were provided in advance and class time was used to discuss the readings, listen to guest speakers, study design methods, and practice these methods in small groups.

To get the most out of the studio learning sessions, students were encouraged to read the materials in advance, develop discussion questions, and come prepared to have an engaging conversation on the topics in the outline. While this was encouraged, the students noted they had a busy semester, so this may not have happened in reality. A way that this might be encouraged in the future is to have a brief "formative submission" on the topics due at the beginning of class.

As teamwork was an area in the literature where engineers noted an explicit role for empathy (Wilson & Mukhopadhyaya, 2022), the students were separated into teams of 3 – 4 individuals. Each group worked with a local Indigenous Nation who gifted them with a project for the duration of a 4-month semester.

The final design project was delivered in three modules: 1) project understanding and initial problem framing 2) engagement, research, and guiding design principles and 3) rapid prototyping, testing, and refined design concept.

In order to *deliberately model empathy-building and its place in engineering*, the students underwent four weeks of empathy-building and self-reflection exercises. In many cases, *additional facility and industry professionals were invited to these sessions* so the students could see that *empathy is a trait that is valued within engineering broadly*, if rarely explicitly discussed.

Activities, guest speakers, and field trips were scheduled at the beginning of the semester in order to promote empathy development, social responsibility, interpersonal skills, and intrinsic motivation. These activities helped students to develop the necessary contextual foundation to allow them to engage in a respectful way with Indigenous peoples. It was very important that they students undertook these activities prior to engaging with the partner Nations. The activities included:

- Indigenous cultural acumen training provided by the University of Victoria's First Peoples' House highlighted the history of colonization, residential schools, Indian hospitals, and government policies such as the Indian Act.
- KAIROS Blanket Exercise at the First Peoples House on the University Campus. The KAIROS Blanket Exercise is an experiential activity that highlights the impacts of colonization on Indigenous Nations across Canada. It is facilitated by a KAIROS practitioner.
- Guided field trips to the reserves of the partner Indigenous Nations (undertaken after the Indigenous Cultural Acumen Training so the students had a foundation of understanding).

After the initial empathy-building activities and development of the students' foundational knowledge, representatives of each Indigenous Nation attended a project kick-off ceremony were students were given a project. During this event, the importance of each project was highlighted.

To *focus on students developing professional identities*, a significant component of this course centred around supporting the students to develop a self-reflective design mindset (self-awareness). Self-reflection is critical in "frame creation" - understanding that diverse worldviews and perspectives are held by Others (Schwandt, 1999) (Dorst, 2015). For this process, self-awareness is vital. To build self-awareness and practice emotional self-expression, students practiced self-reflection through weekly, low-stakes reflective writing. This enabled them to grapple with the difficult emotions they were facing in learning, some for the first time, of Canada's dark history with Indigenous peoples and the ongoing impacts of descriptive government policy. It enabled the instructors and Teaching Assistants to *adopt the role of coaches* and *attend to students developing professional identities* through formative feedback.

Being mindful of the pitfalls of developing self-identities and challenging "self-schemas", the self-reflection exercises were an opportunity for students to position themselves within the context of the

material they were learning. In-class discussions provided students with the opportunity to see how Others were positioning themselves within the context similarly, or differently – showing that many worldviews exist (self-awareness / empathy). It was a safe place to ask hard questions, challenge what they were learning, and receive formative feedback from instructors to guide their learning.

The foundation of self-reflection and historical context gave students the tools necessary to create appropriate problem frames based on empathy. The students' active participation in this course supported the development of this skill by challenging their personal biases and traditions through empathy-building experiences, readings, field trips, guest speakers, weekly learning journals, formative feedback, and the design project. During class sessions, students applied the material from the online lectures, reflecting on the underlying principles and lessons, and discussed their insights with their peers.

In order to *support intrinsic motivations*, the students participated in real-world challenges posed by partner Indigenous Nations. Students understood that the solutions they co-developed with the partner communities had the potential to support infrastructure development ,environmental regeneration, and improved socio-economic outcomes within that community. Students were encouraged to keep this in mind as they worked throughout the semester. The students were able to connect the projects to the historical context of Canada's history with Indigenous peoples introduced through experiential learning activities. Students were able to encouraged to see how their work connected to the broader work reconciliation in Canada (social responsibility). .

Each student also received two sessions of 1-on-1 coaching with a coach training in the development of emotional intelligence. One pre-course, and one post-course. During these sessions, they worked on developing their goals for the course and their personal and professional lives (further supporting the

development of a “whole” professional). The pre and post-course assessments provided quantitative data on how the students' emotional intelligence shifted throughout the semester.

Table 6 - Targeted Areas of EI by Activity

Activity	**Targeted composite or sub-category of EI**
Cultural acumen training, KAIROS, guided field-trips	Empathy
Self-reflective writing	Self-expression, self-awareness, self-perception
In-class discussions	Interpersonal, empathy, self-awareness
Group work	Interpersonal
Real-world projects	Social responsibility, empathy, self-perception

3.3.2 Course Level Intended Learning Outcomes (ILOs)

The Course Level Learning Outcomes were to:

1. Apply the tools and mindset of design and systems thinking to produce good solutions to wicked problems.
2. Experience how the technical capabilities of engineers can be augmented with qualitative research techniques to build empathy and support problem framing.
3. Develop a self-reflective design mindset to appreciate diverse perspectives and worldviews to produce culturally appropriate engineering designs.
4. Identify and understand present-day and historical barriers to infrastructure development in Indigenous Nations.
5. Appreciate the importance of appropriate engagement protocols and relationship building with Indigenous Nations.

6. Employ technical competencies and human-centred design techniques such as rapid prototyping to develop engineering designs that satisfy community-specified needs with appropriate attention to health, safety, economic, environmental, cultural and societal considerations.

3.3.3 Focusing on the Less-Developed Graduate Attributes:

The Canadian Engineering Accreditation Board CEAB outlines 12 graduate attributes. The literature on empathy in engineering suggests that engineering education focuses heavily on technical competencies possibly at the expense of social competencies (such as empathy) (Wilson & Mukhopadhyaya, Role of empathy in engineering education and practice in North America.", 2022). This course was designed to target less-developed graduate attributes related to social competence. This course supported the development of the following graduate attributes:

Investigation:

Students conducted investigations of issues facing Indigenous communities and gathered qualitative data to allow them to appropriately frame the design challenge based on community-identified needs.

Design:

Students employed techniques of human-centred design to meet community-specified needs with appropriate attention to health and safety risks, applicable standards, and economic, environmental, cultural and societal considerations.

Individual and team work:

Students worked in collaborative environment, developing a "whole systems" solution to a "wicked problem" facing a partner Nation or organization.

Impact of engineering on society and the environment:

Through self-reflective writings, students considered their roll as an engineer in society and the motivations that led them to enter the engineering discipline. This was done through weekly learning journals and formative feedback. Attention was paid to how engineers protect public interest, their duty to society and the environment, the historic and contemporary impacts of infrastructure and infrastructure development in Indigenous Nations and an emphasis on a systems view of challenges – seeing the connections between all things.

Students gained an appreciation for social and environmental interconnectedness and the impact of engineering activities on complex societal systems. They gained firsthand experience with this complexity and implemented a co-design approach intended to produce community-led solutions to wicked problems.

3.3.4 Design Modules

The course was developed to help "scaffold" students' approaches to the final project. They were given ample opportunity to complete portions of this final project during class time, reducing their cognitive load, and allowing the instructors to be available for questions and feedback. The final projects consisted of three modules that built on one another, due at regular intervals during the semester to help students manage their time. The design projects that students had the opportunity to be involved in are shown in Table 7, below:

Table 7 - Student Projects and Descriptions

Project Title	**Description**
Clam Garden Planning	Partner with a local Nation who is doing extensive work to develop a Clam Garden in the Southern Gulf Islands to revitalize traditional harvesting practices. Regional infrastructure such as marinas,

	sewer lines, and roadways have caused widespread closures of bi-valve harvesting. This infringes on the Nations Douglas Treaty Rights and traditional ways of life. Site visits may be required and may require travel by boat.
Creek Restoration	A local First Nation has undergone extensive work (with continued work envisioned) to rehabilitate a culturally significant stream and salmon habitat that has been polluted by inappropriate human activity in the area, dating back decades. Due to the installation of a culvert system at the mouth of the estuary, the salmon run has died out, as well as other culturally significant practices tied to the watershed.
Subdivision Design	A local First Nation is developing a subdivision to provide additional housing for its members.
Infrastructure Servicing and Expansion Plan	A neighbouring First Nation is looking to expand their community. This will require significant upgrades to community infrastructure and requires a comprehensive servicing plan for existing infrastructure.

Carving Facility Design	The local Indigenous led Not-for-Profit Organization has established the IPCA Innovation Centre with a regional campus in Clayoquot Sound. As part of the cultural restoration component of this project they have aspirations to build a traditional carving shed for a local Nuu-chah-nulth carver.
Cemetery Expansion Planning	A cemetery in a neighbouring First Nation is not meeting their needs. They have plans to expand the cemetery.
Recreation Field Planning	A local First Nation is working closely local industry to provide parking and laydown area for upcoming projects. In reciprocity the local industry will develop this area into a park at the completion of an upcoming project. The Nation needs plans for recreational field.

Module 1: Project understanding and initial framing

Students drew on the empathy-building experiences in the course (such as the KAIROS Blanket Exercise, cultural acumen training, the project kick-off Ceremony, and the community tours) and interactions with the Nation representatives working with their groups to formulate a short (3-page) project brief. This brief provided background information about the Nation, discussed the challenge and its importance to the Nation, and captured the nature of the problem in a human-centred problem frame. They were

encouraged to study the self-determined goals and objectives of the Nation partner as stated in any publically available Comprehensive Community Plans and aim to connect the project to the larger vision of the Nation. This was shared with the Nation representatives for feedback and revision for future design modules.

Module 2: Engagement strategy, research overview, insights, and guiding design principles

In this module students employed the design tools learned in class about co-design and qualitative research to discuss their 'ideal' engagement strategy with the Nation (what they would have liked to do if they had more time than what was possible in a 4-month semester).

Students also discussed the actual engagement strategy they employed and summarized any fieldwork they conducted. Students were able to use the cultural acumen training, KAIROS Blanket Exercise, Project Kick-off Ceremony, and Community Tours as part of their field research. They were encouraged to discuss how these activities built empathy, shifted mindsets or led to a greater understanding of the project context.

Many students engaged in additional field research such as attending community forums, elders circles, and Nation-directed field trips. For example:

1. Students engaged in the clam garden project participated in a traditional Indigenous practice of aerating the sand - intended to provide additional oxygen for bi-valves.
2. Students engaged in the creek restoration project conducted a walk of the estuary with biologists to catalogue the impact of road infrastructure and pollution on the riparian area.
3. Students engaged in the design for the carving facility travelled to Clayoquot Sound to meet with a local carver to learn about traditional canoe carving practices.
4. Students analyzed and synthesized insights from the qualitative data they collected to generate insights that formed the basis of guiding design principles for their projects.

Module 3: Rapid prototyping, testing, and refined design concept

Once the students developed an appropriate problem frame and produced insight-based guiding design principles, they began to explore the concept "solution space". This was done through an iterative process of divergent and convergent thinking. "Rapid prototyping" was introduced as a helpful tool to explore potential design concepts.

In this module students documented their rapid prototyping and selection process. They chose one concept based on feedback from the Nation partners and developed a more refined prototype.

To support the students' technical communication skills, they produced a final technical report that detailed the proposed design. They were encouraged to discuss with the Nation partners any additional presentations of the design concepts that would be useful for the Nation (for example, something that could be used as the basis for future funding applications, for instance). Students also practiced their communication skills as they produced a high-level executive summary (non-technical) as a "Nation-member facing" document that can be shared with the general Nation membership who may not have a technical background.

3.4 Data Collection and Analysis

3.4.1 Research Ethics Approval

As this study included gathering data from human subjects (students), an extensive research ethics approval was obtained through the University of Victoria Human Research Ethics Board. The certificate can be found in Appendix D.

3.4.2 Quantitative Emotional Intelligence Inventory

It was noted during the literature review that most of the literature on this subject is qualitative in nature. The previous studies have done a fantastic job of exploring this relatively new research area. However, in order to determine the success of this intervention, it was important in include a reliable quantitative tool to measuring Emotional intelligence (including empathy) before and after the course. This was accomplished through an Emotional intelligence Inventory – namely the EQ-i Inventory.

There are three categories of emotional intelligence inventories – trait, mixed, and ability (O'Connor, Hill, Kaya, & Martin, 2019). The recommendation from a comprehensive literature review conducted by O'Connor et al. in 2019 was that researchers should select trait EI measures when they are interested in measuring behaviour tendencies and/or emotional self-efficacy (O'Connor, Hill, Kaya, & Martin, 2019). In addition, this study suggested that non-experts should choose a trait EI inventory as they have "good psychometric properties, do not have questionable theoretical bases and correlate moderately and meaningfully with a broad set of outcome variables" (O'Connor, Hill, Kaya, & Martin, 2019).

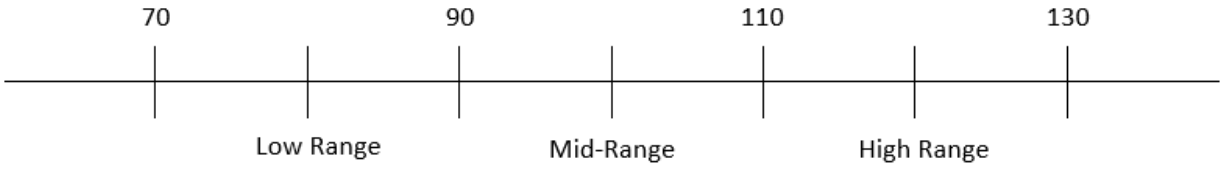
Criticisms of trait emotional intelligence tests are that they can be easily manipulated by participants not answering truthfully, by the proportionally low number of questions contributing to certain parameters, or by the participants' mood upon taking the test. It should also be noted that the language used and training provided in interventions such as this course may also skew results, particularly if participants are aware that a certain outcome is desired. However, a 2019 comprehensive literature review by O'Connor et. al shows that the EQ-I inventory has had "extensive research" and shows some support for reliability and validity (O'Connor, Hill, Kaya, & Martin, 2019). They suggest that the strongest current evidence for construct and predictive validity are the self-report/trait EI measures (O'Connor, Hill, Kaya, & Martin, 2019). As such, this is the tool that was used in the research initiative described in this paper, despite its limitations.

One such measure of trait EI discussed in the literature review by O'Connor et al. is EQ- I "The Emotional intelligence Inventory". EQ-i is a comparative tool that employs a questionnaire to break down one's total emotional intelligence (EI) into five composite scores as shown in Table 8. These composite scores are in turn broken down into 15 sub-categories. The scores are then compared to a database of other people in a similar age range or peer group that have taken the inventory and a score is provided. The composite categories and subcategories are as follows.

Table 8 - Composite Categories of Emotional Intelligence EQi 2.0

Composite Category	**Sub-categories**
Self-perception	Self-regard, Self-Actualization, Emotional Self-Awareness
Self-expression	Emotional Expression, Assertiveness, Independence
Interpersonal	Interpersonal Relationships, Empathy, Social responsibility
Decision making	Problem Solving, Reality Testing, Impulse Control
Stress management	Flexibility, Stress Tolerance, Optimism

Values are provided in a range from 60 points to 140 points. As shown in the figure below, a low range is defined as having a score of less than 90 points. A mid-range is defined as a score between 90 points and 120 points. A high range is 120 to 140 points.



3.4.3 Chosen Emotional Intelligence Composites and Sub-categories

For this paper, overall emotional intelligence, as well as the sub-categories of empathy, emotional self-awareness, and social responsibility were tracked as well as the composite scores of self-perception, self-expression, and interpersonal.

Total emotional intelligence was a chosen parameter as the authors determined it to be a best analogy to the general term “social competence” that is noted in the literature as lacking within engineering graduates.

Empathy was included as it is the basis of empathetic design frameworks such as design thinking and systems thinking and represents the ability to understand the feeling of another.

Emotional self-awareness was included as it is closest to “personal-awareness” or “self-awareness”. Self-awareness is needed for an understanding of one’s own beliefs, thoughts, motivations, biases, and recognizing how they affect others (Hurley, Linsley, & Stansfield, 2011). This is a foundational concept of understanding diverse world-views, a critical skill in Design Thinking. The composite score of self-perception was included to elaborate on the results of the emotional self-awareness sub-category. Self-reflective writing was used as a way to develop self-awareness.

Social responsibility was included as it was one of the variables included in the study by Cech in 2014 that decreased in light of interventions aimed at improving social responsibility and social competence (Cech, 2014).

3.4.4 Quantitative Statistical Methods

Of the 30 students enrolled in the course, 17 participated fully in the pre-semester and post-semester emotional intelligence Inventories. As it was a requirement by the testing agency delivering the EQi2.0 inventories for the students to review their results with a trained professional, there was some difficulty in arranging these meetings and receiving the EQi2.0 reports before the end of the semester. This is why participation was limited to 17 students.

Statistical Method – Paired t-test

Quantitative data was analyzed using a paired t-test, typically used to test the means of a population before and after some intervention. This is an appropriate test to measure for statistical significance, particularly when the data is normally distributed, specifically when the differences in the paired samples is normally distributed. The confidence interval α is 0.05 (95% confidence interval). The sample size n is 17, and the number of degrees of freedom is 16. This leads to a critical t value of 1.745.

The data was tested for statistical significance using equation 1, below:

Equation 1: $$t = \frac{\bar{x} - \mu_d}{s_d/\sqrt{n}} \text{ and } p < 0.05$$

Where $\bar{x}$ is the sample mean of the difference between the two data sets, μ_d is the mean difference, s_d is the sample standard deviation, and n is the sample size. If the calculated value of t was greater than $t_{critical}$, the data was determined to fall into the rejection region of the null hypothesis.

Q-Q plot to assess for Normal Distribution

Data sets were checked for normal distribution using a Q-Q (quantile-quantile) plot. The Q-Q plot is a graphical method used to assess whether a dataset follows a normal distribution (or other statistical

model). It compares the quantiles of the sample data with those of a normal distribution. If the data points on the Q-Q plot roughly follow a straight diagonal line, the data is likely to be normally distributed. Q-Q-plots were created for pre and post-intervention data sets, as well as for the differences between paired measurements. Confirmation of normal distribution in the data provides further validity for the statistical methods used, and further reliability to the findings.

A linear trend line was added and the linear regression (R^2) value was determined to approximate the fit of the trend line to the data. The R^2 value is a value between 0 and 1 that gives a statistical measure of how well the regression line approximates the actual data, with 1 being a perfect fit. While the Q-Q plots are useful for assessing if a data set is normally distributed, there are several challenges that must be considered when applied to small sample sizes. These limitations can make interpretation of the Q-Q diagrams challenging and potentially misleading. For instance, a small sample size may conceal meaningful deviations from the normal distribution such as heavy tails or skew. Conversely, small samples may appear to deviate from normality even if the underlying population is normally distributed at larger sample sizes. Additionally, in small sample sizes, a few outliers can strongly affect the Q-Q plot. It should be noted that due to random sampling, what may seem like an outlier in the data set may actually be part of the normal distribution at the tail ends of the distribution. With larger data sets, outliers have less impact and the overall shape of the distribution becomes clearer.

1.5 Inter-Quartile Range (IQR) method to assess outliers.

As discussed above due to the small sample size, what may seem like an outlier in the data set may actually be part of the normal distribution at the tail ends of the distribution. This is a limitation of the statistical determination of an outlier as discussed above. Outlying data points should be analyzed in greater detail using the qualitative writings of the subjects to determine if there is reasonable justification for removing or keeping the outlying data. This was done ins section 3.6.

From a statistical perspective, outliers in the data were determined using the 1.5 x Inter-Quartile Range (IQR) method, where the IQR is determined as the difference between the third quartile value (Q3) and the first quartile value (Q1). When analyzing the pre-and-post-semester difference in each parameter, any data point greater than Q3 + 1.5IQR was considered an outlier. Similarly, data points below Q1 – 1.5IQR were considered outliers. Outlying data points as determined using the 1.5IQR method were excluded from the data set. This provided a more conservative calculation for statistical significance due to the removal of degrees of freedom.

Confidence Interval

The 95% confidence interval was constructed using the equation 2:

Equation 2:

$$95\%\ Confidence\ Interval\ = \bar{x}\ \pm\ t_{crit}\frac{s_d}{\sqrt{n}}$$

And provides additional information to either reject or accept the null hypothesis.

Cohen's d for paired t-test

Cohen's d is a standardized measure of the effect size. It provides insights into the effect of an intervention. It is calculated using the following equation:

$$d = \frac{mean\ of\ differences}{standard\ deviation\ of\ differences}$$

A larger Cohen's d means a stronger effect or greater change between the paired measurements. It is generally interpreted as follows:

- 0.2 represents a small effect of the intervention
- 0.5 represents a medium effect of the intervention
- 0.8 represents a large effect of the intervention

3.4.5 Qualitative Methods

As a means to provide further validity to the quantitative results, the students' learning journals and final self-reflections were used to provide some qualitative insight into the results of the quantitative analysis.

Using the qualitative data from the learning journals, the students journey through the course was documented, outlining what the students were feeling, how they were integrating their learning, and how they were applying their learning to their projects.

Using the data from the students' final reflections, main themes were identified that indicated which learning strategies and experiences were most effective at creating shifts in their emotional intelligence. The qualitative writings were used to provide some justification as to the efficacy of the course in producing any noted changes.

Qualitative data was coded using NVIVO 15. NVIVO 15 is a qualitative analysis software designed to help researchers organize, analyze, and synthesize the results of qualitative data. It is widely used across various disciplines in academia that focus on the collection and analysis of qualitative data.

3.5 Quantitative Results

3.5.1 Change in Overall Emotional Intelligence

As shown in Table 9, the overall change in total emotional intelligence as measured through the EQi2.0 inventory throughout the semester ranged from -5 points (indicating a decrease in overall emotional intelligence) to 21.8 points. The 1.5IQR method determined that the data would be considered an outlier if the difference in pre and post-course values was greater than 22.1 points or less than -8 points. No outliers were noted in the data. Of the 17 students who participated fully in the emotional

intelligence Inventories, 76% (13 of 17) showed an increase in emotional intelligence, while 18% (3 of 17) showed a decrease and 6% (1 of 17) showed no change. The average increase was 5.4 points.

Table 9 - Data Points: Change in Emotional Intelligence

Student ID	Pre-Course EI	Post -Course EI	Change
Student 2	104.2	112.6	8.4
Student 3	106.2	117	10.8
Student 4	90	108.2	18.2
Student 6	99.6	108.8	9.2
Student 7	107.8	112.6	4.8
Student 8	103.6	102	-1.6
Student 13	100	100	0
Student 14	106.4	107.4	1
Student 16	96.4	103.4	7
Student 17	96.4	91.4	-5
Student 18	105	102.6	-2.4
Student 20	99	101.6	2.6
Student 21	107.2	129	21.8
Student 22	111.6	112.2	0.6
Student 23	107	109.6	2.6
Student 25	94.6	105	10.4
Student 27	106.2	109.6	3.4

The aggregate emotional intelligence profiles of the students were plotted on a radar diagram. While there was significant variation in the data between students, the aggregate data shows an increase in all five of the composite categories of emotional intelligence as shown in Figure 5. Figure 6 shows the changes in overall emotional intelligence by student.

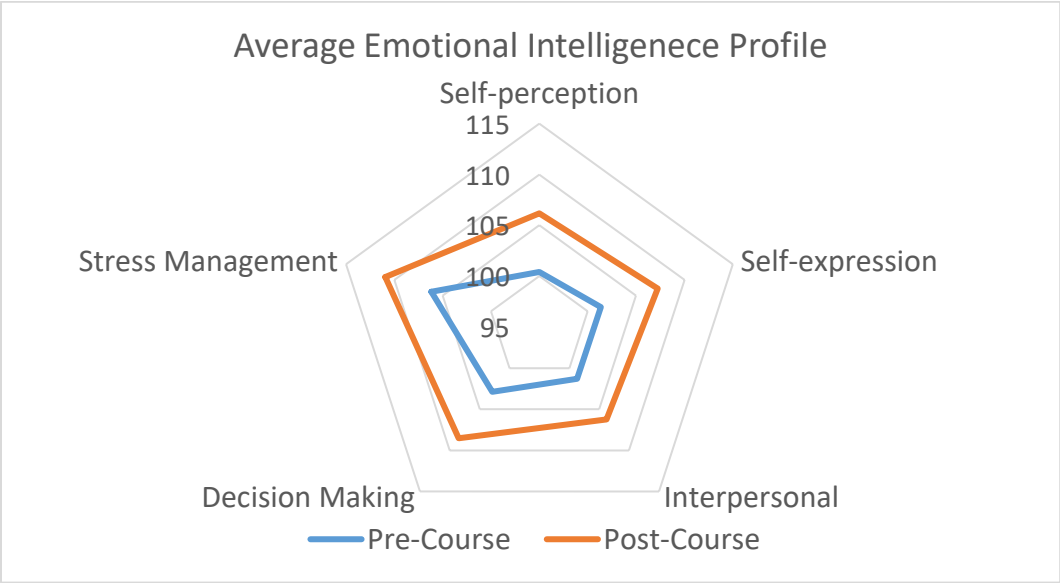


Figure 5 - Radar Diagram: Change in Aggregate Emotional intelligence

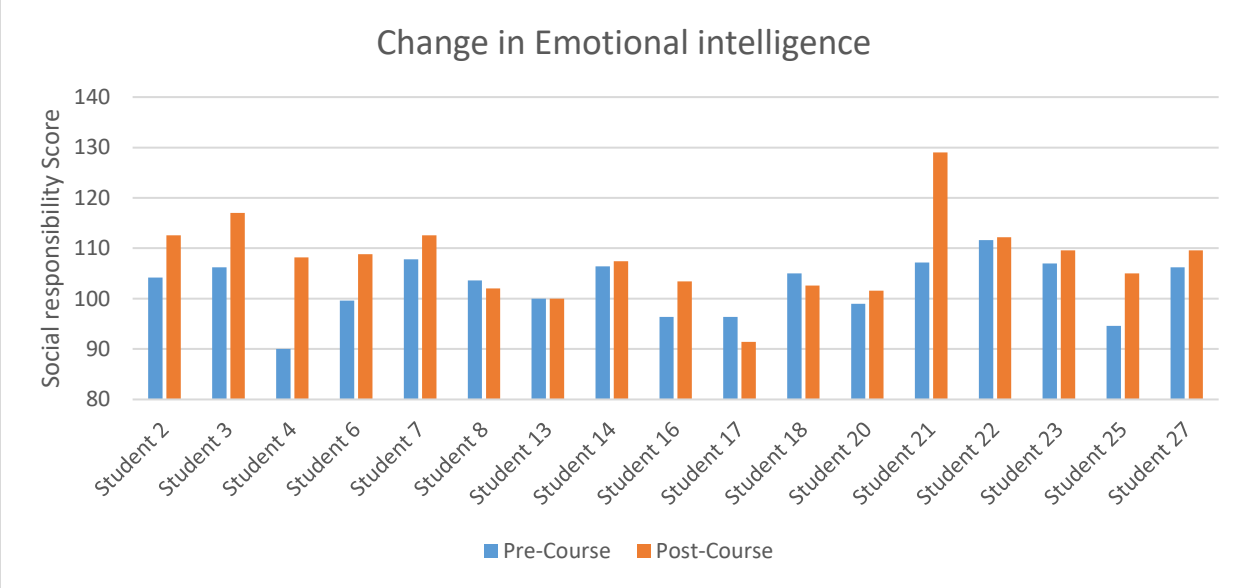


Figure 6 - Bar Chart: Change in Individual Emotional Intelligence

Verification of Normal Distribution – Q-Q Plot

The pre and post semester data sets were checked for normal distribution using a Q-Q (quantile-quantile) plot.

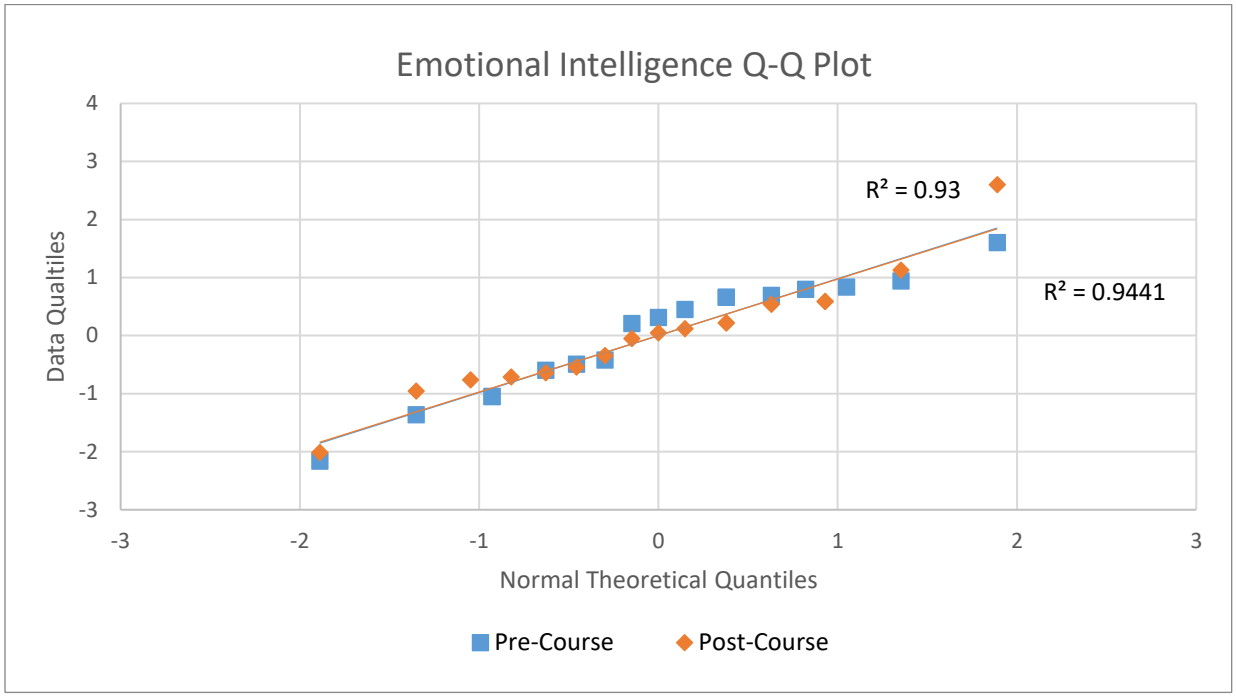


Figure 7 - Emotional Intelligence Q-Q-Plot

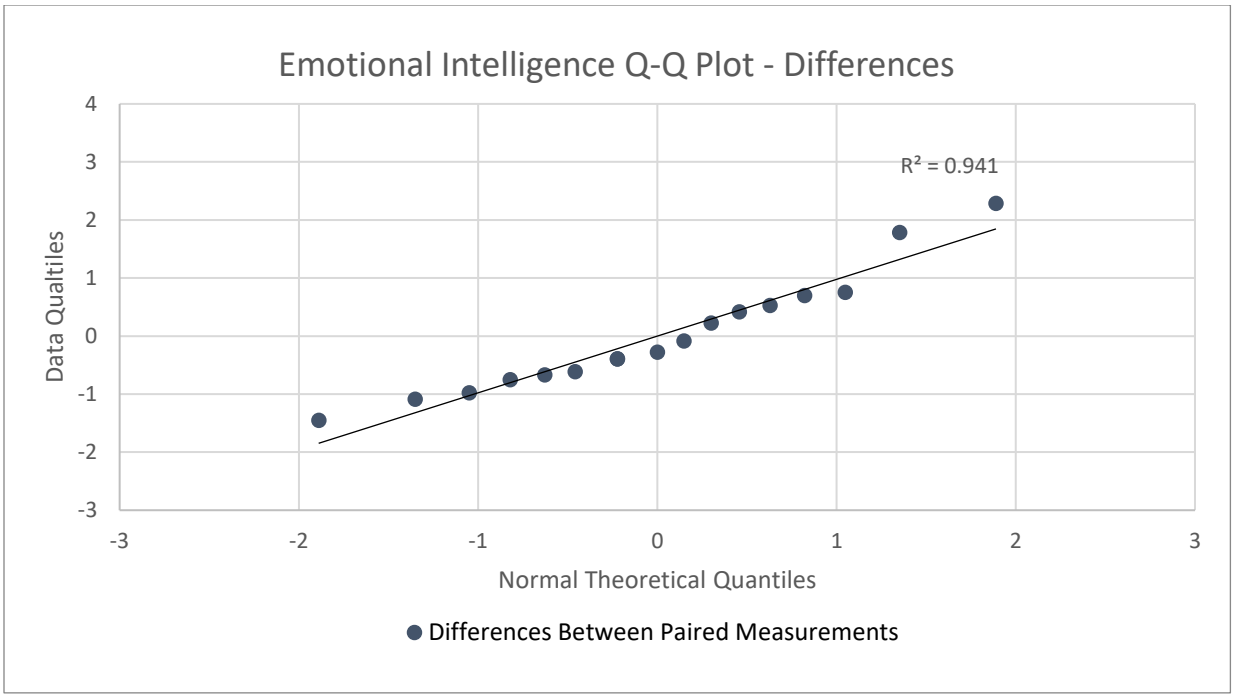


Figure 8 - Emotional Intelligence Q-Q Plot - Differences in Paired Measurements

As can be seen in the Q-Q diagrams, the pre and post semester data is roughly linear, indicating the data likely follows a normal distribution. The data showing the differences between the paired measurements is also likely represented by a normal distribution due to the linearity of the trend-line and the high R-square value. This implies that the paired t-test will be a useful statistical method to determine significance.

Using equation 1 above, the results in Table 10 show that the calculated t-value for this data set was found to be 3.105 and the p-value was found to be 0.0034 indicating that the null hypothesis (that the course had no impact on emotional intelligence) should be rejected with 95% confidence. The data shows a statistically significant increase in the measured levels of total emotional intelligence post-intervention. The 95% confidence interval suggests that the change in Emotional intelligence lies between the values of 2.36 points and 8.43 points. The Cohen's d for this data set was 0.75, indicating a medium-to-large effect of the intervention.

Table 10 - t-Test: Paired Two Sample for Means: Change in Overall EI

	Post -class EI	*Pre-class EI*
Mean	107.8235294	102.4235
Variance	66.46441176	32.87941
Observations	17	17
Pearson Correlation	0.512690741	
Hypothesized Mean Difference	0	
df	16	
t Stat	3.105234614	
P(T<=t) one-tail	0.003402424	
t Critical one-tail	1.745883676	

3.5.2 Change in Empathy

As shown in Table 11, the overall change in sub-category of empathy throughout the semester ranged from -5 points (indicating a decrease in overall empathy) to 22 points. Of the 17 students who participated fully in the emotional intelligence Inventories, 53% (9 of 17) showed an increase in empathy, while 18% (3 of 17) showed a decrease and 30% (5 of 17) had no change. The average increase was 3.17 points and the standard deviation was 6.47 points. Figure 9 shows the changes in empathy by student.

Table 11 - Data Points: Change in Empathy

Student ID	Pre-Course Empathy	Post -Course Empathy	Change
Student 2	96	110	14
Student 3	83	86	3
Student 4	91	96	5
Student 6	99	102	3
Student 7	91	86	-5
Student 8	99	102	3

Student 13	99	99	0
Student 14	104	102	-2
Student 16	107	115	8
Student 17	83	86	3
Student 18	104	104	0
Student 20	88	86	-2
Student 21	104	126	22
Student 22	123	123	0
Student 23	102	102	0
Student 25	94	94	0
Student 27	102	104	2

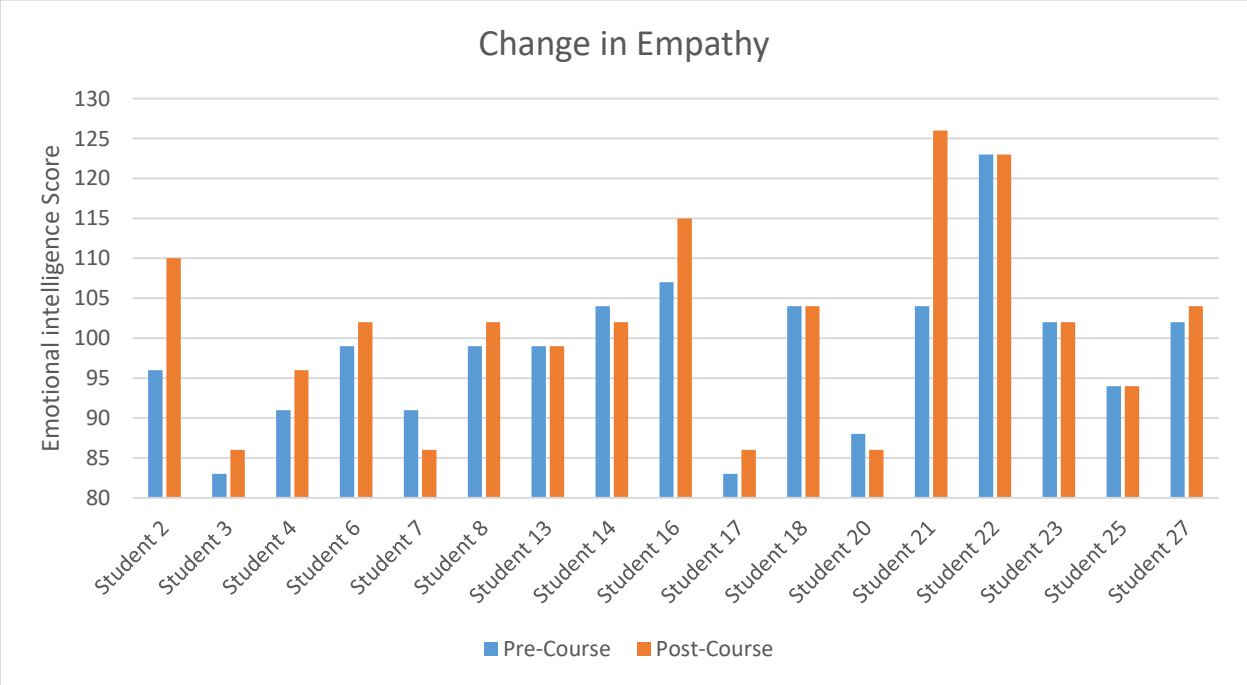


Figure 9 - Bar Chart: Change in Empathy

Verification of Normal Distribution – Q-Q Plot

The pre and post semester data sets were checked for normal distribution using a Q-Q (quantile-quantile) plot.

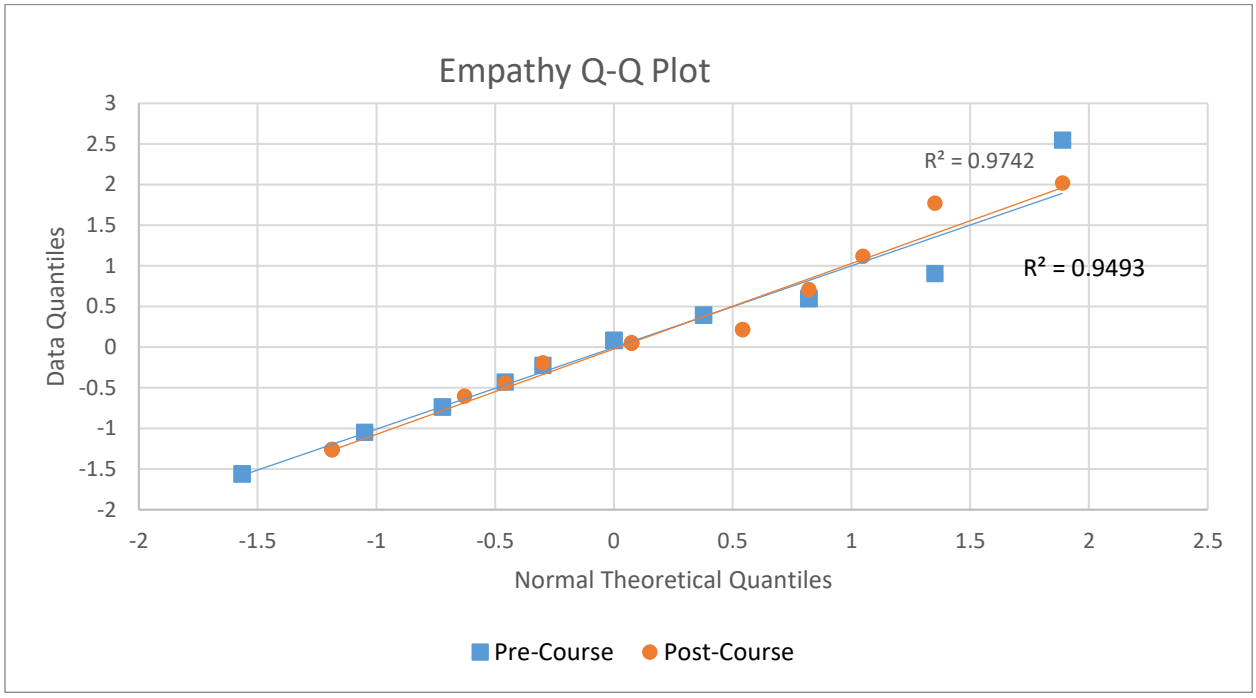


Figure 10 - Empathy Q-Q-Plot

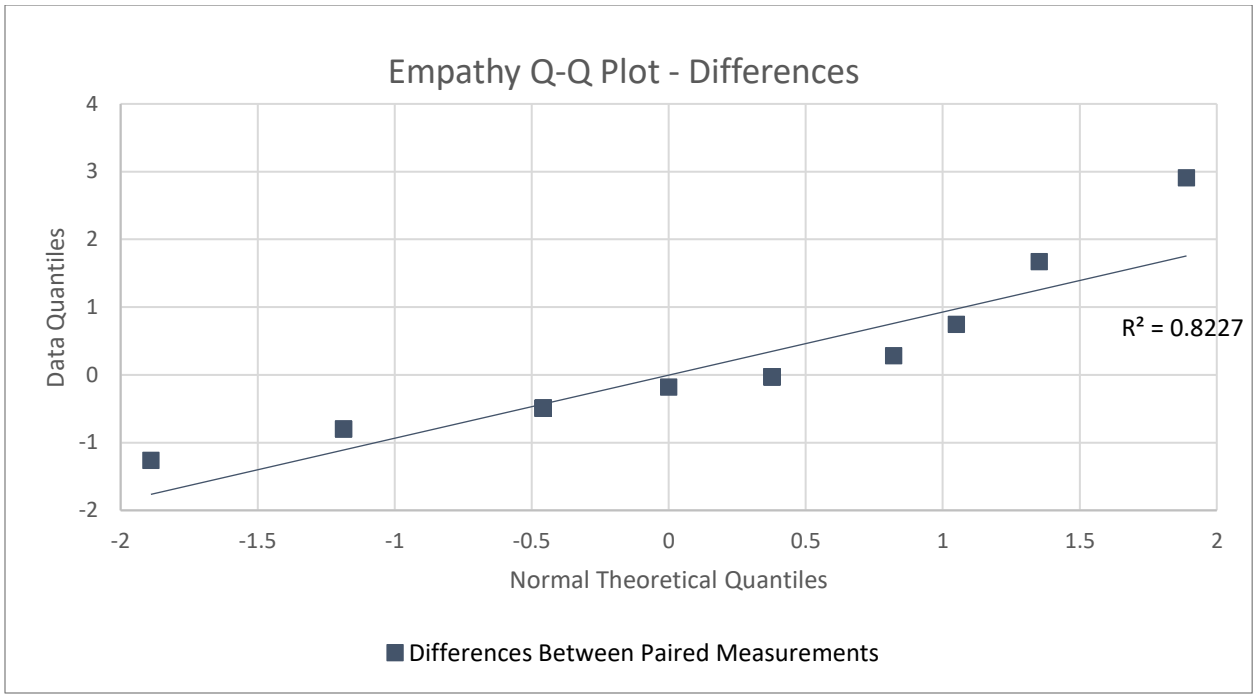


Figure 11 - Empathy Q-Q Plot - Differences in Paired Measurements

As can be seen in the Q-Q plots, pre and post semester data fit well to linear trend lines indicating that the data may be normally distributed. Outliers can be seen in the data sets, which will impact the data fit to the linear trend line. The data showing the differences between the paired measurements is also likely represented by a normal distribution, but the R-squared value is 0.82, likely being skewed by the outlying data. It is important to note that this data may not be an outlier, but just a data point at the tail end of the distribution.

The data fit to the linear trend lines implies that the data is likely normally distributed and that the paired t-test will be a useful statistical method to determine significance.

Similarly, to above, the change in the students' empathy was analyzed using a paired t-test as shown in Table 12. The results show that the critical t-value is 1.745, the calculated t-value is 2.023, and the p-value is 0.03, indicating that the null-hypothesis should be rejected and showing a statistically significant increase in the measured levels of empathy post-intervention.

Table 12 - t-Test Paired Two Sample for Means: Change in Empathy

	Post--Class Empathy	*Pre-class Empathy*
Mean	101.3529412	98.17647
Variance	148.9926471	94.77941
Observations	17	17
Pearson Correlation	0.849370754	
Hypothesized Mean Difference	0	
df	16	
t Stat	2.023202835	
P(T<=t) one-tail	0.030045139	
t Critical one-tail	1.745883676	

Potential Outliers

The 1.5IQR method determined that the data may be considered an outlier if the difference in pre and post course values was greater than 7.5 points or less than -5 points. In the data set measuring empathy, four potential outliers were noted as highlighted in Table 13.

Table 13 - Highlighting Potential Outliers in the Empathy Data

Student ID	Pre-Course Empathy	Post -Course Empathy	Change
Student 2	96	110	14
Student 3	83	86	3
Student 4	91	96	5
Student 6	99	102	3
Student 7	91	86	-5
Student 8	99	102	3
Student 13	99	99	0
Student 14	104	102	-2
Student 16	107	115	8

Student 17	83	86	3
Student 18	104	104	0
Student 20	88	86	-2
Student 21	104	126	22
Student 22	123	123	0
Student 23	102	102	0
Student 25	94	94	0
Student 27	102	104	2

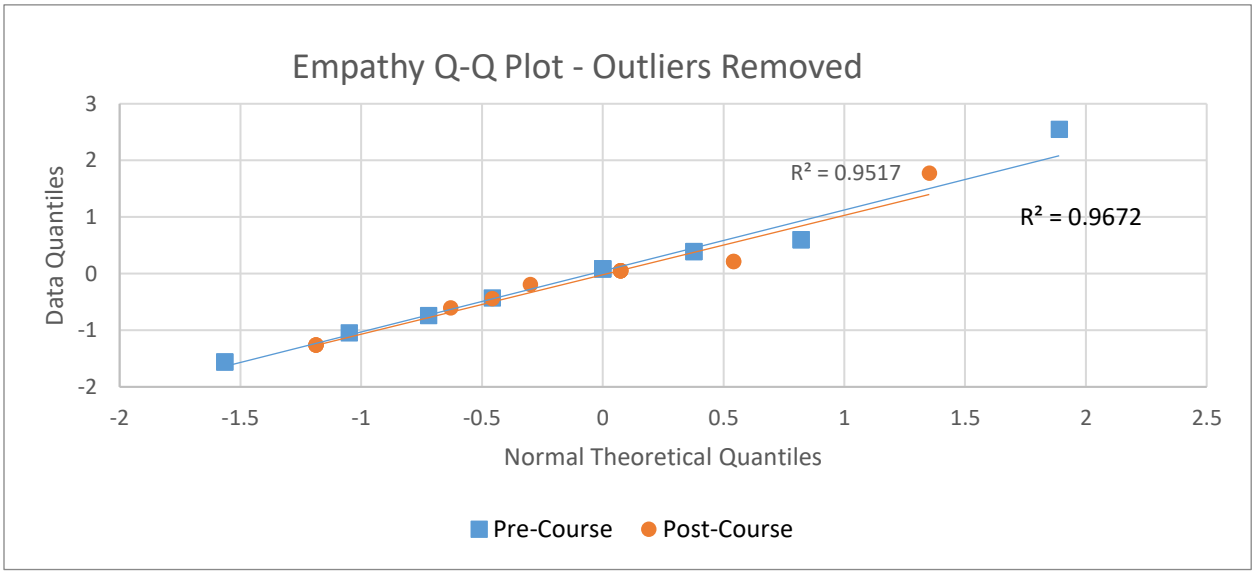


Figure 12 - Empathy Q-Q Plot: Outliers Removed

Removing the noted data-points from the data set and re-checking the trend lines shows an improvement and greater conformance to a normal distribution in the differences between paired measurements plot shown in Figure 13. However, removing the data points will also make it harder to

achieve significance at this sample size.

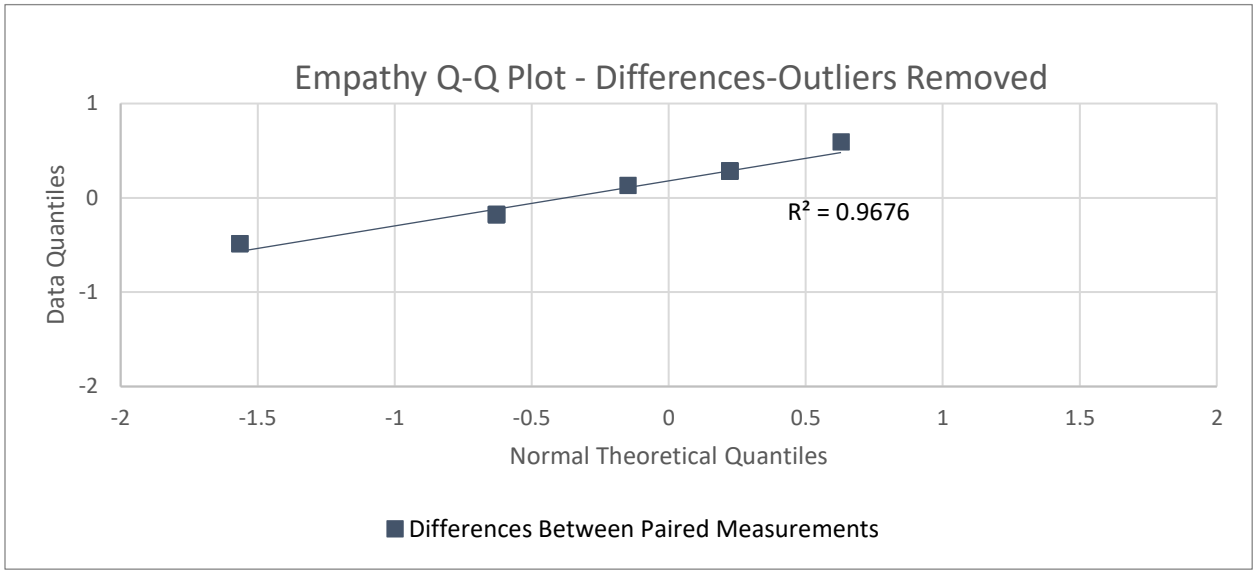


Figure 13E - Empathy Q-Q Plot - Differences in Paired Measurements Outliers Removed

Therefore the statistical significance was re-calculated. It was found that the critical t-value is 1.782 (due to a reduction in the degrees of freedom), the calculated t-value is 1.93, and the p-value is 0.039, indicating that the null-hypothesis should be still rejected and the increase in value noted in the data post-intervention remained statistically significant. The 95% confidence interval suggests the change in empathy is between 0.11 points and 2.2 points. The Cohen's d for this data set was 0.54, indicating a medium effect of the intervention.

3.5.3 Change in Social Responsibility

As above, the students' social responsibility was tracked pre-semester and post-semester. This was included as previous interventions intended to increase the social competencies of engineering students discussed in the literature showed decreases in a similar parameter (social consciousness) the longer students spent in engineering education (Cech, 2014).

As shown Table 14 and Figure 14, the overall change in social responsibility throughout the semester ranged from -15 points (indicating a decrease in overall emotional intelligence) to 19 points. The 1.5IQR

method determined that the data may be considered an outlier if the difference in pre and post course values was greater than 27.5 points or less than -16.5 points. No potential outliers were noted in the data set.

Of the 17 students who participated fully in the emotional intelligence Inventories, 65% (11 of 17) showed an increase in emotional intelligence, while 18% (3 of 17) showed a decrease and 18% (3 of 17) showed no change. The average increase was 5.11 points and the standard deviation was 8.67 points.

Table 14 - Data Points: Change in Social Responsibility

Student ID	Pre-Course Social responsibility	Post -Course Social responsibility	Change
Student 2	107	118	11
Student 3	111	122	11
Student 4	107	118	11
Student 6	104	115	11
Student 7	93	100	7
Student 8	85	104	19
Student 13	93	93	0
Student 14	104	104	0
Student 16	93	104	11
Student 17	93	96	3
Student 18	104	89	-15
Student 20	107	100	-7
Student 21	115	129	14
Student 22	129	125	-4

Student 23	107	111	4
Student 25	89	100	11
Student 27	104	104	0

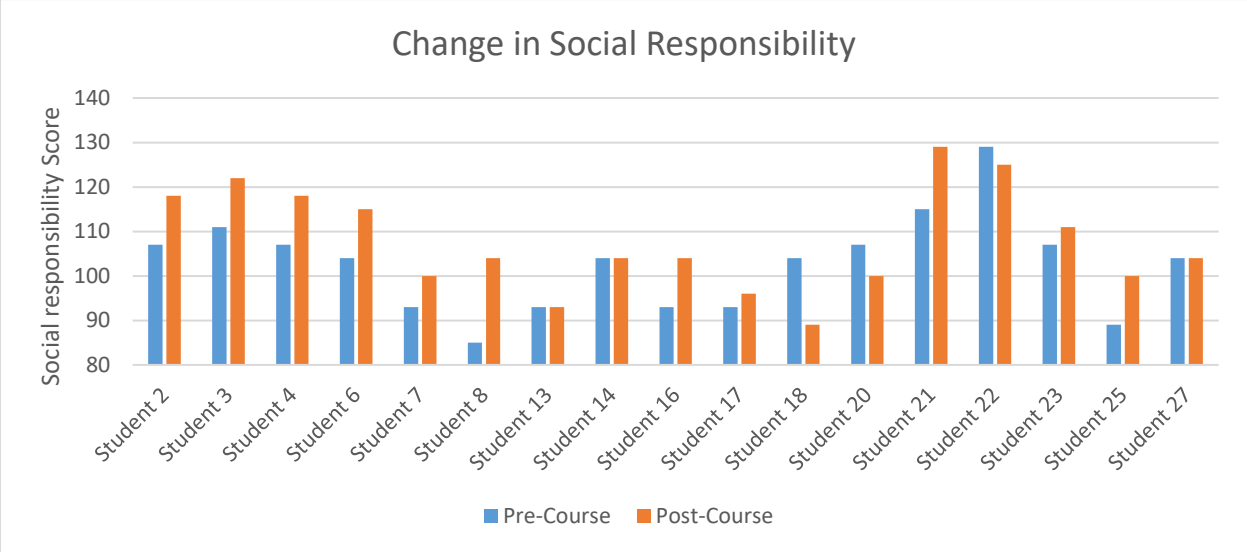


Figure 14 - Change in Social Responsibility

Verification of Normal Distribution – Q-Q Plot

The pre and post semester data sets were checked for normal distribution using a Q-Q (quantile-quantile) plot.

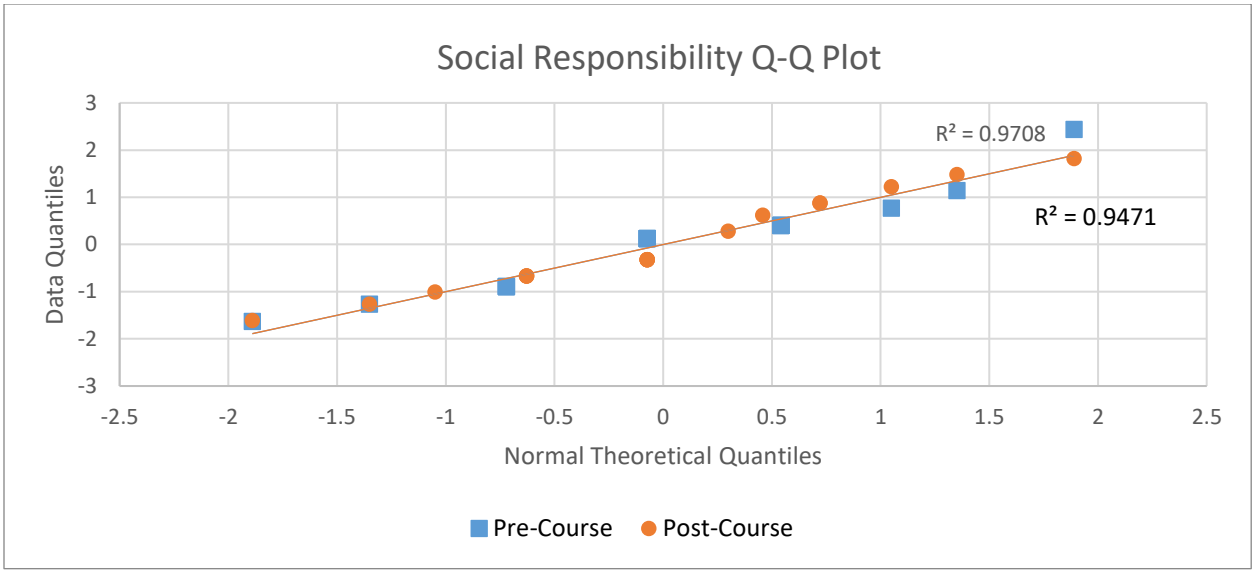


Figure 15 - Social Responsibility Q-Q-Plot

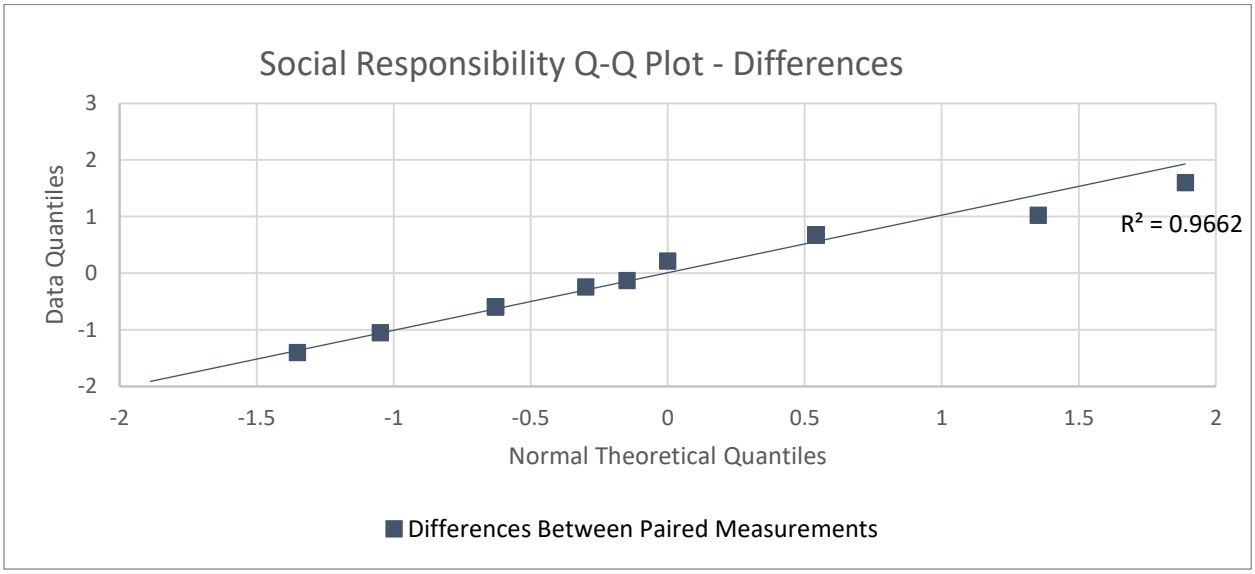


Figure 16 –Social Responsibility Q-Q Plot - Differences in Paired Measurements

As can be seen in the Q-Q plots in Figures 15 and 16, pre and post semester data fit well to linear trend lines indicating that the data may be normally distributed and that the paired t-test will be a useful statistical method to determine significance.

As above, the change in the students' social responsibility was analyzed using a paired t-test. The results shown in Table 15 indicate that the critical t-value is 1.745, the calculated t-value is 2.43, and the p-

value is 0.013, indicating that the null hypothesis should be rejected with 95% confidence and showing a statistically significant increase in the measured levels of Social responsibility post-intervention. The 95% confidence interval indicates that the change in Social responsibility post-intervention falls between 1.44 points and 8.78 points. The Cohen's d for this data set was 0.59, indicating a medium effect of the intervention.

Table 15 - t-Test Paired Two Sample for Means - Change in Social Responsibility

	Post -class Social responsibility	*Pre-class Social responsibility*
Mean	107.7647059	102.6471
Variance	135.5661765	116.8676
Observations	17	17
Pearson Correlation	0.704390593	
Hypothesized Mean Difference	0	
df	16	
t Stat	2.434697785	
P(T<=t) one-tail	0.013492998	
t Critical one-tail	1.745883676	

3.5.4 Change in Emotional Self-Awareness

As above, the students' Emotional Self-awareness was tracked pre-semester and post-semester.

As shown in Table 16 and Figure 17, the overall change in emotional self-awareness throughout the semester ranged from -18 points (indicating a decrease in overall emotional intelligence) to 25 points. The 1.5IQR method determined that the data may be considered an outlier if the difference in pre and post course values was greater than 39.5 points or less than -20 points. No potential outliers were noted in the data set.

Of the 17 students who participated fully in the emotional intelligence inventories, 47% (8 of 17) showed an increase in emotional self-awareness, while 30% (5 of 17) showed a decrease and 24% (4 of

17) showed no change. The average increase was 4.18 points and the standard deviation was 11.9 points.

Table 16 - Data Points: Change in Emotional Self-Awareness

Student ID	Pre-Course Emotional Self-Awareness	Post -Course Emotional Self-Awareness	Change
Student 2	111	125	14
Student 3	103	111	8
Student 4	71	85	14
Student 6	103	114	11
Student 7	114	114	0
Student 8	103	96	-7
Student 13	75	75	0
Student 14	96	93	-3
Student 16	103	89	-14
Student 17	89	71	-18
Student 18	85	107	22
Student 20	85	82	-3
Student 21	107	132	25
Student 22	114	114	0
Student 23	100	107	7
Student 25	85	100	15
Student 27	96	96	0

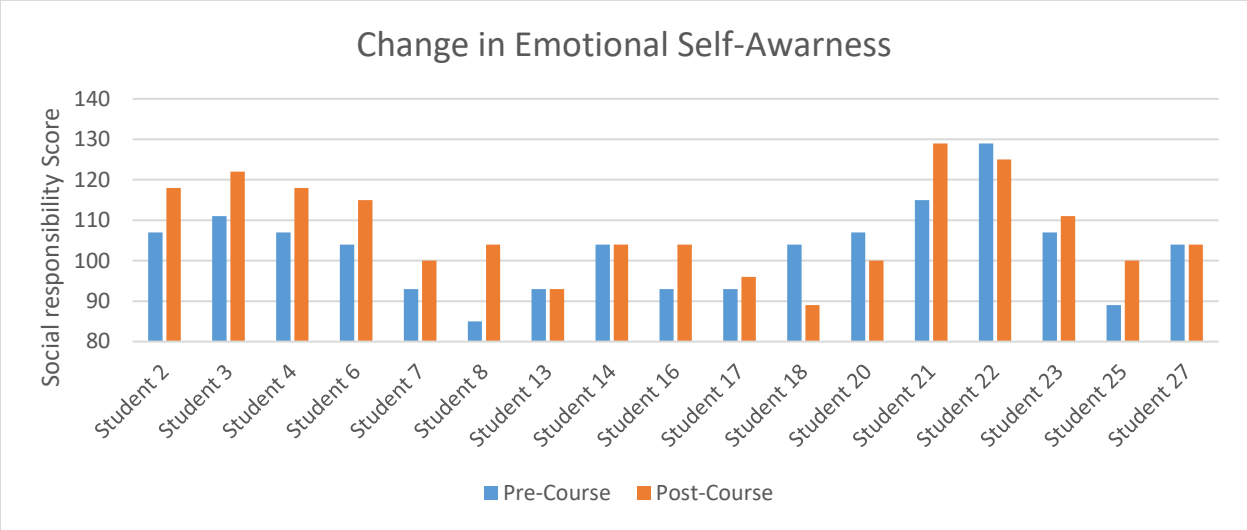


Figure 17 - Change in Emotional Self-Awareness

Verification of Normal Distribution – Q-Q Plot

The pre and post semester data sets were checked for normal distribution using a Q-Q (quantile-quantile) plot.

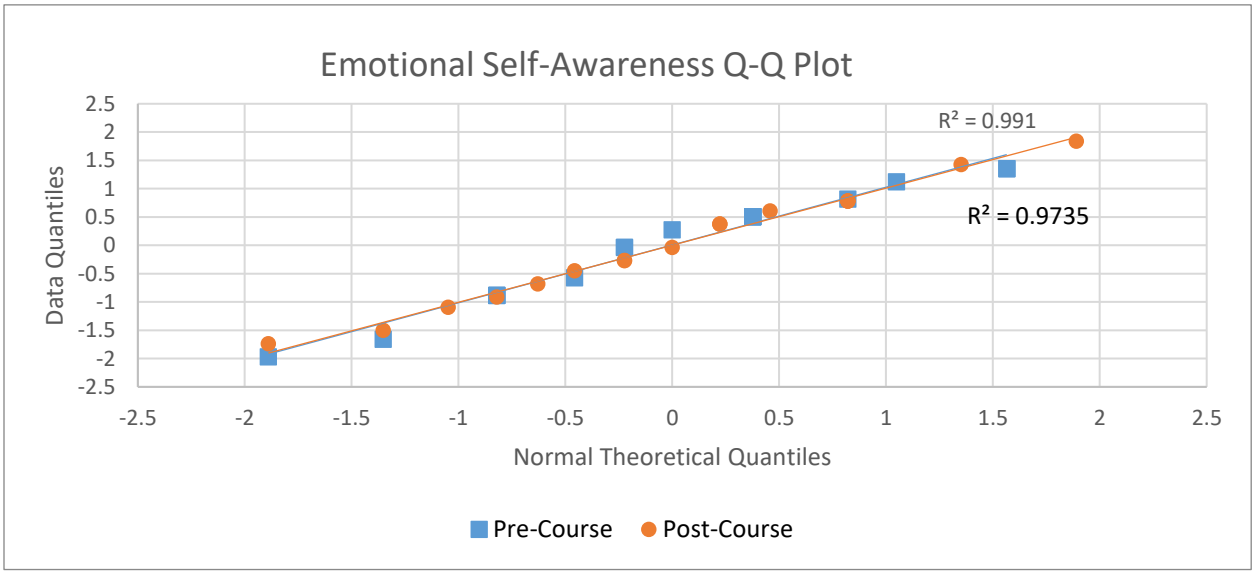


Figure 18 - Social Responsibility Q-Q-Plot

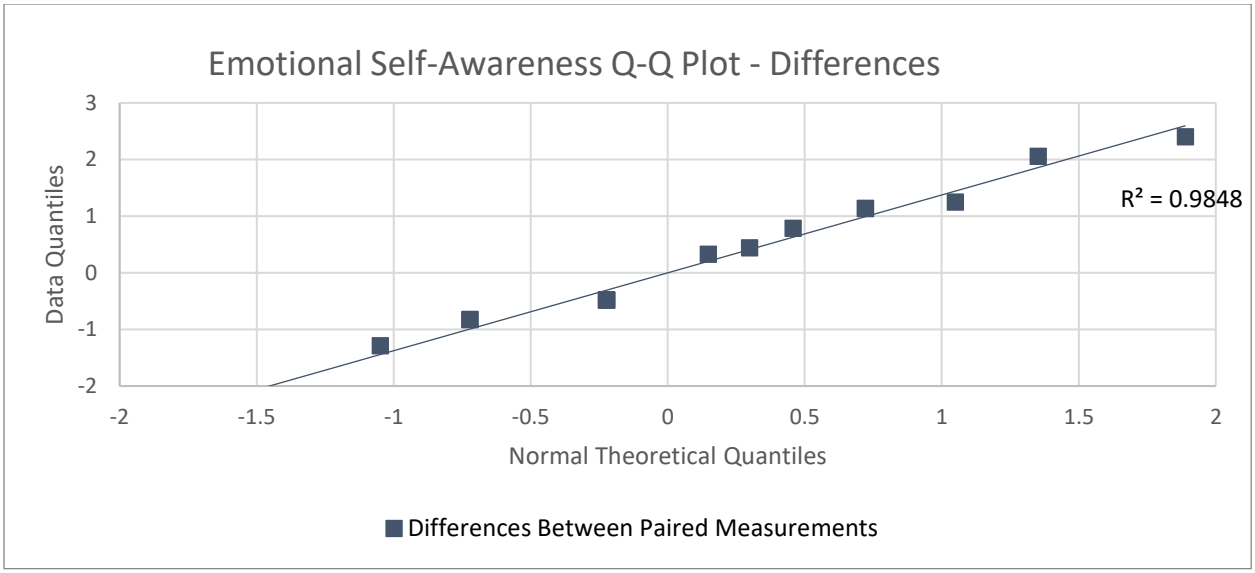


Figure 19 - Social Responsibility Q-Q Plot - Differences in Paired Measurements

As can be seen in the Q-Q plots, in Figure 18 and 19 pre and post semester data fit well to linear trend lines indicating that the data may be normally distributed and that the paired t-test will be a useful statistical method to determine significance.

As above, the change in the students' Emotional Self-Expression was analyzed using a paired t-test. The results shown in Table 17 indicate that the critical t-value is 1.745, the calculated t-value is 1.45, and the p-value is 0.083, indicating that the null hypothesis should not be rejected. The change to emotional self –expression was not statistically significant. The Cohen's d for this data set was 0.35, indicating a small-to-medium effect of the intervention.

Table 17 - t-Test Paired Two Sample for Means - Change in Emotional Self-Awareness

t-Test: Paired Two Sample for Means

	Variable 1	*Variable 2*
Mean	100.6470588	96.47059
Variance	291.6176471	167.5147
Observations	17	17
Pearson Correlation	0.720470148	
Hypothesized Mean Difference	0	
df	16	
t Stat	1.451968547	

P(T<=t) one-tail	0.082918745
t Critical one-tail	1.745883676

3.5.5 Change in Self-Perception Composite

As described in Table 8, the self-perception composite is comprised of self-regard, self-Actualization, and emotional self-awareness. As shown in Table 18 and Figure 20, the overall change in self-perception throughout the semester ranged from -9 points to 21 points. The 1.5IQR method determined that the data may be considered an outlier if the difference in pre and post-course values was greater than 25 points or less than -10 points. No potential outliers were noted in the data set.

Of the 17 students who participated fully in the emotional intelligence Inventories, 71% (12 of 17) showed an increase in self-expression, while 24% (4 of 17) showed a decrease and 6% (1 of 17) showed no change. The average increase was 5.76 points and the standard deviation was 8.58 points.

Table 18 - Data Points: Change in Self-Perception

Student ID	Pre-Course Self-Perception	Post-Course Self-Perception	Change
Student 2	106	118	12
Student 3	116	125	9
Student 4	73	92	19
Student 6	99	114	15
Student 7	117	125	8
Student 8	100	91	-9
Student 13	83	83	0
Student 14	107	106	-1

Student 16	95	98	3
Student 17	106	98	-8
Student 18	104	112	8
Student 20	85	90	5
Student 21	108	129	21
Student 22	108	110	2
Student 23	102	110	8
Student 25	99	109	10
Student 27	99	95	-4

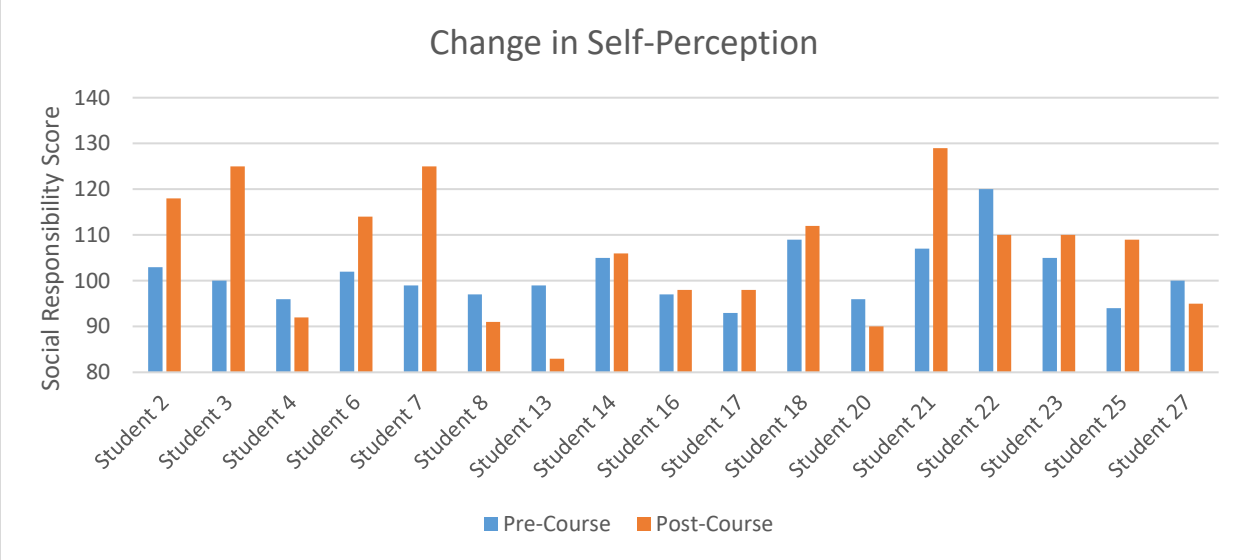


Figure 20 - Bar-Chart: Change in Self-Perception

Verification of Normal Distribution – Q-Q Plot

The pre and post semester data sets were checked for normal distribution using a Q-Q (quantile-quantile) plot.

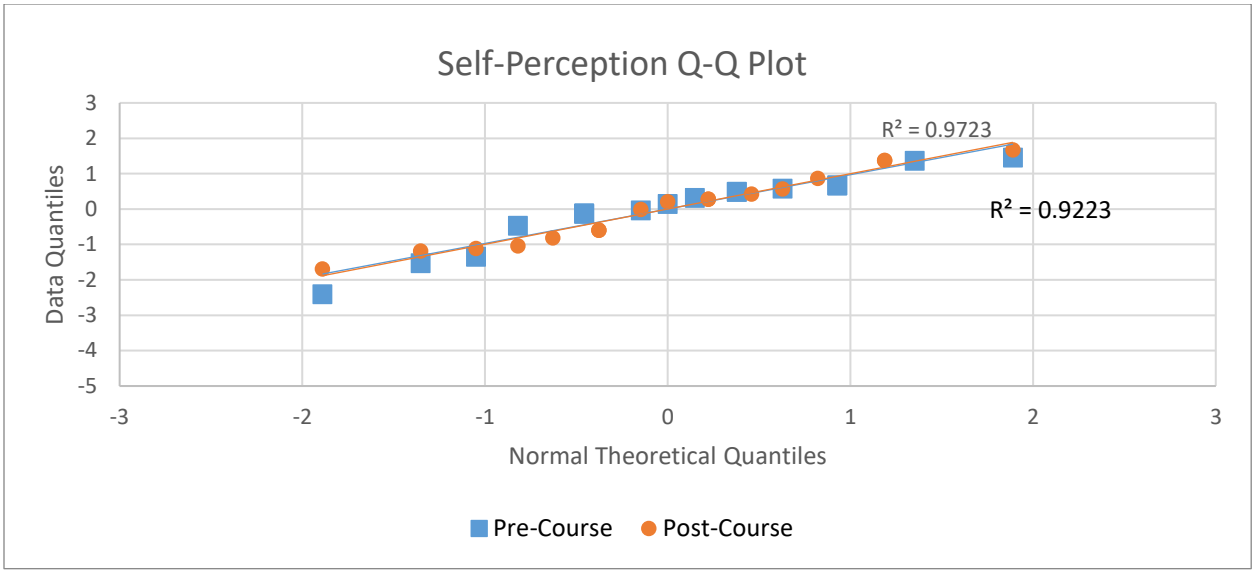


Figure 21 - Self-Perception Q-Q-Plot

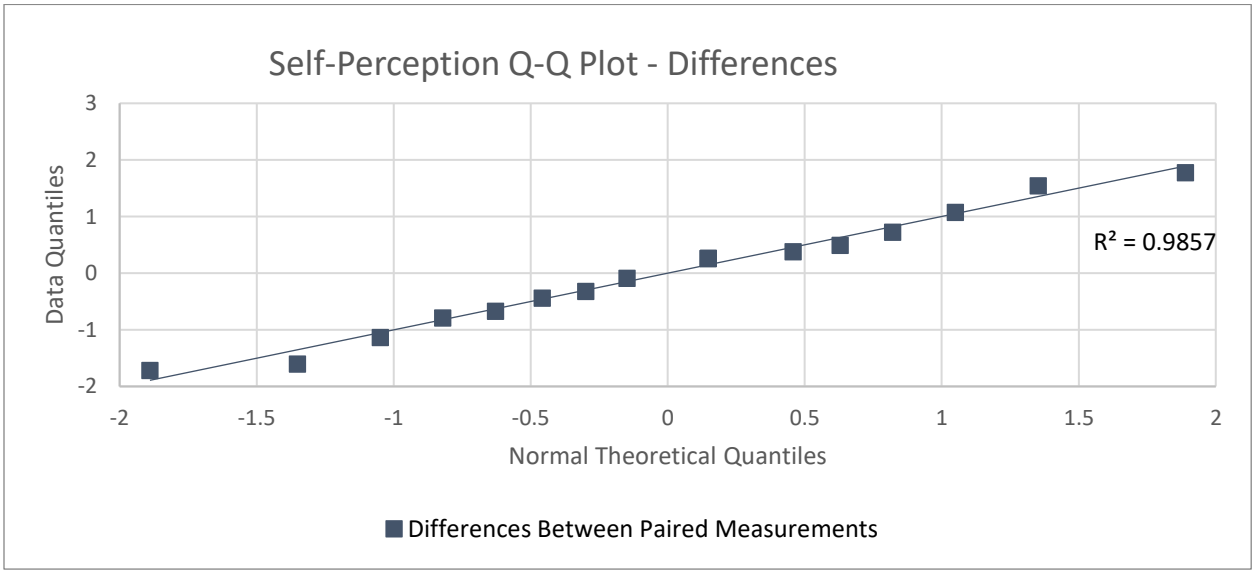


Figure 22 - Self-Perception Q-Q Plot - Differences in Paired Measurements

As can be seen in the Q-Q plots in Figures 21 and 22, pre and post semester data fit well to linear trend lines indicating that the data may be normally distributed and that the paired t-test will be a useful statistical method to determine significance

The change in the students' self-perception was analyzed using a paired t-test. The results shown in Table 19 indicate that the critical t-value is 1.745, the calculated t-value is 2.513, and the p-value is 0.01,

indicating that the null hypothesis should be rejected with 95% confidence and showing a statistically significant increase in the measured levels of self-perception post-intervention. The 95% confidence interval suggests that the increase in self-perception falls between 2.13 points and 9.39 points. The Cohen's d for this data set was 0.67, indicating a medium effect of the intervention.

Table 19 - t-Test: Paired Two Sample for Means: Change in Self-Perception

	Post-Class	*Pre-Class*
Mean	106.2352941	101.2941
Variance	98.06617647	43.84559
Observations	17	17
Pearson Correlation	0.581248202	
Hypothesized Mean Difference	0	
df	16	
t Stat	2.513770426	
P(T<=t) one-tail	0.011513454	
t Critical one-tail	1.745883676	

3.5.6 Change in Self-Expression Composite

As shown in Table 20 and Figure 23, the overall change in the self-expression composite throughout the semester ranged from -7 points (indicating a decrease in overall emotional intelligence) to 20 points. The 1.5IQR method determined that the data may be considered an outlier if the difference in pre and post-course values was greater than 25 points or less than -10 points. No potential outliers were noted in the data set.

Of the 17 students who participated fully in the emotional intelligence Inventories, 65% (11 of 17) showed an increase in self-expression, while 18% (3 of 17) showed a decrease and 18% (3 of 17) showed no change. The average increase was 5.88 points and the standard deviation was 7.68 points.

Table 20 - Data Points: Change in Self-Expression

Student ID	Pre-Course Self-Expression	Post -Course Self-Expression	Change
Student 2	102	104	2
Student 3	104	118	14
Student 4	83	101	18
Student 6	102	112	10
Student 7	108	117	9
Student 8	107	104	-3
Student 13	94	94	0
Student 14	109	109	0
Student 16	91	103	12
Student 17	82	79	-3
Student 18	109	102	-7
Student 20	93	103	10
Student 21	111	131	20
Student 22	113	113	0
Student 23	104	108	4
Student 25	94	102	8
Student 27	117	123	6

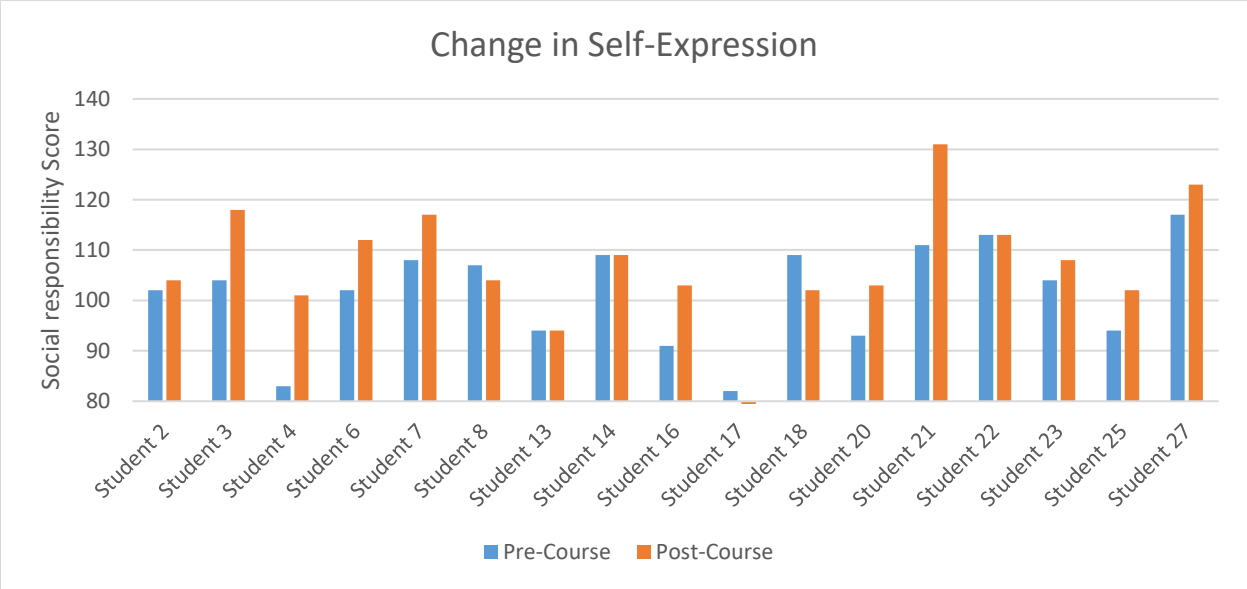


Figure 23 - Bar Chart: Change in Self-Expression

Verification of Normal Distribution – Q-Q Plot

The pre and post semester data sets were checked for normal distribution using a Q-Q (quantile-quantile) plot.

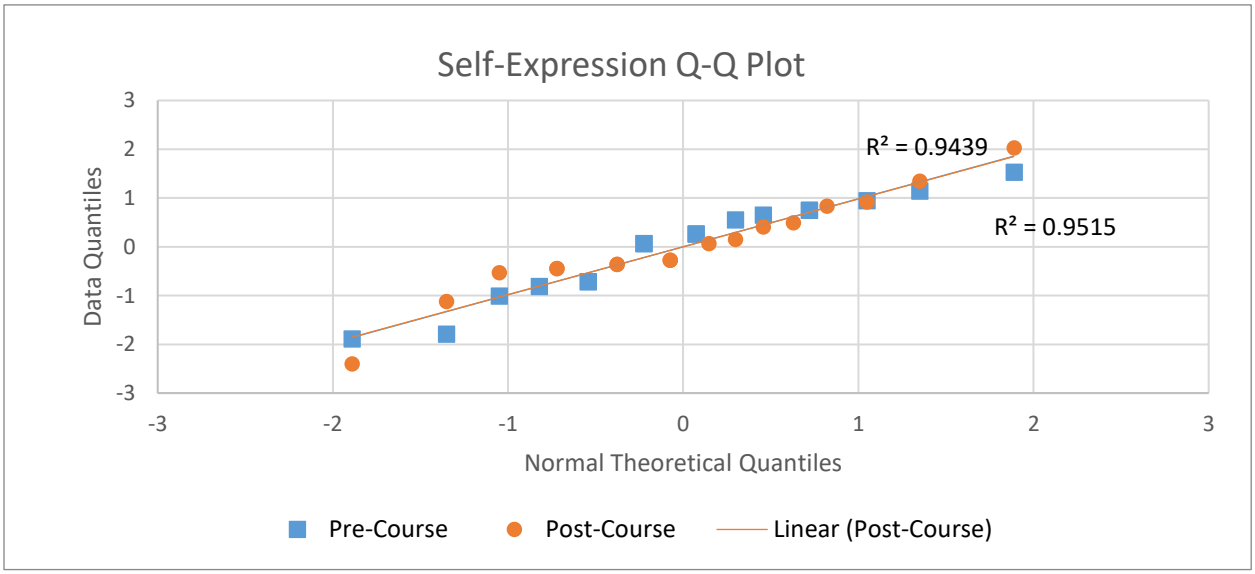


Figure 24 - Self-Expression Q-Q-Plot

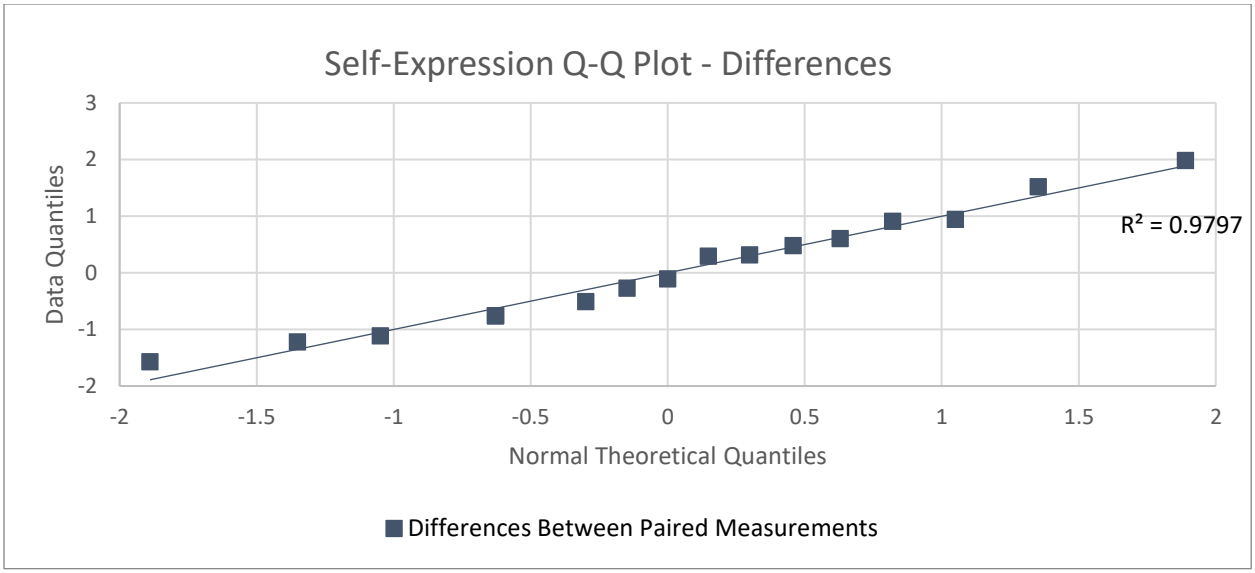


Figure 25 - Self-Expression Q-Q Plot - Differences in Paired Measurements

As can be seen in the Q-Q plots in Figures 23 and 24, pre and post semester data fit well to linear trend lines indicating that the data may be normally distributed and that the paired t-test will be a useful statistical method to determine significance.

The change in the students' self-expression was analyzed using a paired t-test. The results shown in Table 21 indicate that the critical t-value is 1.745, the calculated t-value is 3.16, and the p-value is 0.003, indicating that the null hypothesis should be rejected with 95% confidence and showing a statistically significant increase in the measured levels of Self-Expression post-intervention. The 95% confidence interval suggests that the increase in Self-Expression falls between 2.63 points and 9.13 points. The Cohen's d for this data set was 0.76, indicating a medium-to-large effect of the intervention.

Table 21 - t-Test Paired Two Sample for Means: Change in Self-Expression

t-Test: Paired Two Sample for Means

	Post - Class EI	*Pre - Class EI*
Mean	107.2352941	101.3529
Variance	137.9411765	104.8676
Observations	17	17
Pearson Correlation	0.764193571	

Hypothesized Mean Difference	0
df	16
t Stat	3.157938476
P(T<=t) one-tail	0.003046423
t Critical one-tail	1.745883676

3.5.7 Change in Interpersonal Composite

As shown in Table 22 and Figure 26, the overall change in the interpersonal composite throughout the semester ranged from -6 points (indicating a decrease in overall emotional intelligence) to 22 points. The 1.5IQR method determined that the data may be considered an outlier if the difference in pre and post-course values was greater than 20 points or less than -8 points. One outlier was noted in the data set.

Of the 16 data points included after outlier were removed, 63% (10 of 16) showed an increase in self-expression, while 25% (4 of 16) showed a decrease, and 12% (2 of 16) showed no change. The average increase was 3.875 points and the standard deviation was 7.03 points.

Table 22 - Data Points: Change in Self-Expression

Student ID	Pre-Course Self-Expression	Post -Course Self-Expression	Change
Student 2	103	120	17
Student 3	100	106	6
Student 4	96	112	16
Student 6	102	109	7
Student 7	99	96	-3
Student 8	97	103	6

Student 13	99	99	0
Student 14	105	102	-3
Student 16	97	108	11
Student 17	93	94	1
Student 18	109	103	-6
Student 20	96	90	-6
Student 21	107	129	22
Student 22	120	120	0
Student 23	105	107	2
Student 25	94	102	8
Student 27	100	106	6

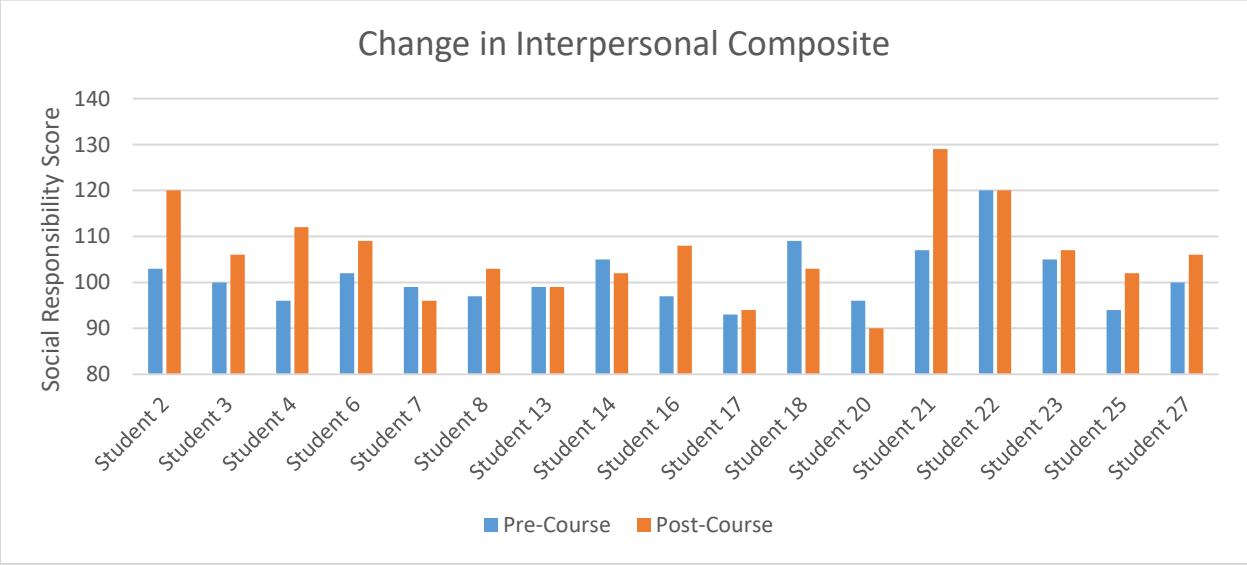


Figure 26 - Bar Chart: Change in Interpersonal Composite

Verification of Normal Distribution – Q-Q Plot

The pre and post semester data sets were checked for normal distribution using a Q-Q (quantile-quantile) plot.

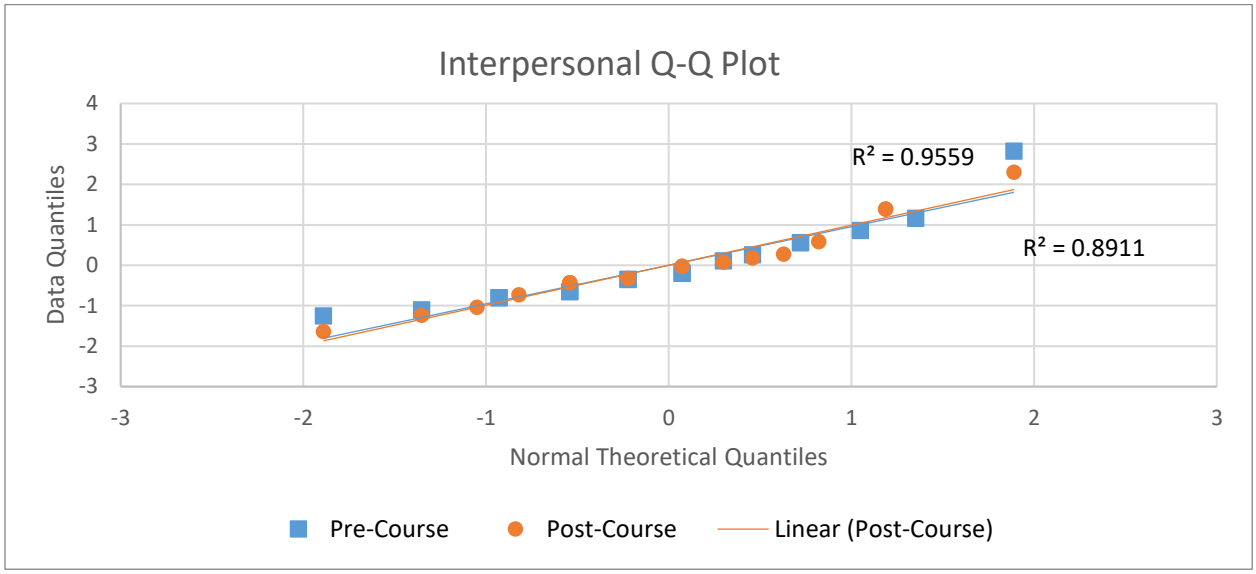


Figure 27 - Interpersonal Q-Q-Plot

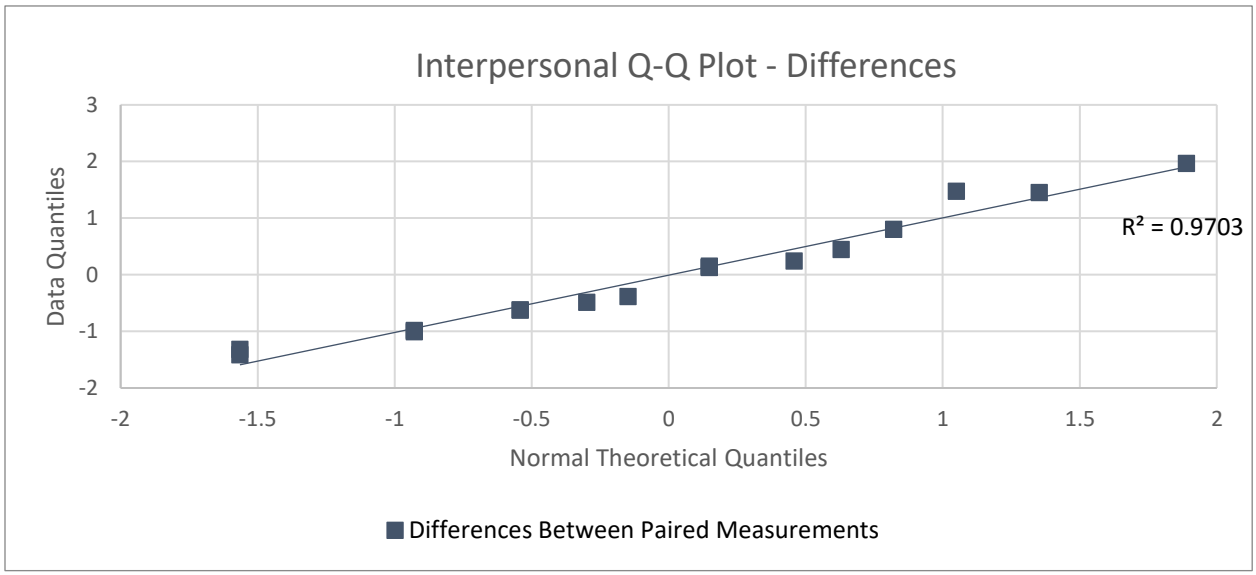


Figure 28 - Interpersonal Q-Q Plot - Differences in Paired Measurements

As can be seen in the Q-Q plots in Figures 27 and 28, pre and post semester data fit well to linear trend lines indicating that the data may be normally distributed and that the paired t-test will be a useful statistical method to determine significance

The change in the students' interpersonal composite was analyzed using a paired t-test. Excluding the outlier, the results shown in Table 23 indicate that the critical t-value is 1.753, the calculated t-value is 2.2, and the p-value is 0.022, indicating that the null hypothesis should be rejected with 95% confidence and showing a statistically significant increase in the measured levels of the Interpersonal Composite post-intervention. The 95% confidence interval suggests that the increase in the interpersonal composite falls between 0.8 points and 6.9 points. The Cohen's d for this data set was 0.55, indicating a medium effect of the intervention.

Table 23 - t-Test Paired Two Sample for Means: Change in Interpersonal Composite

	Post-Class	*Pre-Class*
Mean	104.8125	100.9375
Variance	67.89583333	44.4625
Observations	16	16
Pearson Correlation	0.572479162	
Hypothesized Mean Difference	0	
df	15	
t Stat	2.204187576	
P(T<=t) one-tail	0.021773035	
t Critical one-tail	1.753050356	

3.5.8 Discussion of Quantitative Results

Using statistical analysis, the data set showed statistically significant increases in all parameters of interest (expect emotional self-awareness) post-intervention. For the parameters of interest showing statistically significant increases this indicates that the null hypothesis (that the course would not increase these parameters) should be rejected. Further discussion of the data points showing a decrease in EI parameters is provided through analysis of the qualitative data in section 3.6.

A summary of the quantitative data analysis is provided in the table below.

Table 24 - Summary of Quantitative Data

Parameter	T-stat	p-value	Statistical significance achieved	Cohen's d
Overall emotional intelligence	3.105	0.003	Yes	0.75
Empathy	1.931	0.039	Yes	0.54
Social responsibility	2.435	0.013	Yes	0.59
Emotional self-awareness	1.452	0.083	No	0.35
Self-perception	2.514	0.012	Yes	0.67
Self-expression	3.158	0.003	Yes	0.77
Interpersonal	2.204	0.022	Yes	0.55

A limitation of this study is the small sample size and that it cannot be definitively stated that the intervention resulted in the increase in emotional intelligence and the other composite and sub-categories, however, the results are promising. In addition, the study did not specifically target all 15 sub-categories of emotional intelligence through the course design. However, it is interesting to note that an overall increase in all the composite categories was noted for the students who participated in this study. This may imply that specific activities such as self-reflective writings, field-trips, and group work may impact numerous sub-categories of emotional intelligence simultaneously.

Self-selection bias was not considered a concern in this study, as participation was implied through enrollment in the course (as approved by the human research ethics board). The lower number of study participants compared to total enrolled students was not due to students opting out but rather to logistical challenges. Specifically, many students struggled to schedule the mandatory EQ-i 2.0 coaching debrief session before the deadline for their final learning reflection submission.

The students' personal goals and objectives were not tracked. In conversations with the EQi2.0 coaches, the students may have set goals related to composite categories and sub-categories that were not

deliberately addressed by this course. As such, it is not accurate to say the course was the result of any particular change in EI subcategories that were not explicitly targeted.

There were noted instances where students' scores in these sub-categories or composites decreased throughout the semester, however majority of cases, an increase was noted. The results may be explained by students with a disposition towards empathy and emotional intelligence self-selecting into this course based on their interest in the subject matter. The students in this course may have been predisposed to greater levels of self-awareness and desire for personal growth. The decreases will be explored in greater detail in the qualitative analysis.

Alternatively, the act of taking the emotional intelligence Inventory and being aware of the parameters and questions may bias the post-semester results and be responsible for the increase. Or it may be true, as there seems to be some evidence, that the results from the test are easily skewed. For instance, participants with experience in the EQ-i inventory could answer questions dishonestly to achieve a certain result in the post-semester EQ-i inventory, or feel prompted by the context of the course.

To help validate the data, a control group of students (in the same year as the test group) should be created and analyzed. Ideally, this group would be from a non-elective course as it would be a better representative sample of the student body. A control group was sought for this study in a non-elective 4^{th}-year design course, however, there was not enough interest from the students in spending the time to take the Emotional intelligence inventory twice throughout the semester due to an already significant course load. A control group form this context would give a more representative cross section of the student body as participation in non-elective courses is required. This may indicate that they have little interest in the subject matter to begin with (supporting the self-selection theory) or that they were feeling pressed for time and did not want to add another task to their already busy semesters.

It is interesting to note that the decreases in the parameters did not all occur in the same students. For example, Student 7 showed the largest decrease in empathy (-5 points), but showed an increase in Social responsibility (7 points) and an overall increase in emotional intelligence (4.8 points).

Similarly, Student 20 showed a decrease of 2 points in empathy and 7 points in social responsibility but still exhibited a 2.6-point increase in overall Emotional intelligence. The increases for Student 20 were primarily noted in the categories of self-perception (5-points) and self-expression (10-points).

Student 8 showed a slight increase in empathy (3 points), and a significant increase in social responsibility (19 points), but a slight decrease in overall emotional intelligence.

Changes such as these can be interpreted through analysis of the students' qualitative writings.

To date, research on empathy and social competencies in engineering has largely relied on qualitative methods as this is a fairly nascent area of research. These qualitative studies are not as easily comparable across contexts.

3.6 Validation with Qualitative Data

The statistically significant increases in the measured parameters of emotional intelligence do not necessarily mean the intervention was the cause of the increase, however the verification of the chosen statistical method using the Q-Q plots, and the Cohen's D values offer increased confidence in the results. Qualitative research was also gathered as a means to provide further validity to the results and attribution to the intervention.

The thematic analysis was conducted using NVIVO 15. Qualitative writings were coded and the results of the coding were synthesized to identify overarching themes across the student's reflective writings. Student reflections were reviewed until concept saturation was achieved. Studying data saturation and variability in qualitative inquiry, it was found that "saturation occurred within the first twelve

interviews" and "basic elements for meta-themes were present as early as six interviews" (Guest, Bunce, & Johnson, 2006).

3.6.1 Qualitative Research Questions

3.6.1.1 Learning Journal Research Question

Students were asked to write four learning journals throughout the semester to discuss their thoughts and feelings on the course material. This served to help students integrate their learning from course experiences and activities, process emotions, reflect on personal biases, and receive formative feedback.

The learning journals were analyzed to determine what the students were reflecting on, providing a 'snapshot' of their learning process and emotional state. The research question was therefore:

"what are the key themes in the students' learning process during this phase of the course?".

3.6.1.2 Final Reflection Research Question

The students also produced a final reflective paper, commenting on changes in their emotional intelligence profiles and providing personal insights into the change. Students were asked to discuss what they felt had the greatest impact on their emotional intelligence. This was used to identify which instruction strategies and course experiences were most beneficial and provided credibility to the hypothesis that the course led to the change in their EQ profiles. The research question for this stage of the analysis was: *"To what are students attributing their changes in emotional intelligence?".*

It was important for the generalizability of the study to note which activities the students noted as having a direct impact on the change in their EQ profile.

3.6.2 Learning Journal Analysis

3.6.2.1 Learning Journal 1 - Understanding Context

The phase of the first learning journal can be summarized as "*Understanding Context".* The time period for the first learning journal was within the first three weeks of class. By this time in the course, the students had completed the first EQi 2.0 inventory, KAIROS Blanket Ceremony, Indigenous Cultural Acumen Training, and an assignment reflecting on where they are from geographically. The coding for the thematic analysis of learning journal one is provided in Table 25, below.

Table 25 - Learning Journal 1 Coding Manual

Learning Journal 1: Coding manual			
Theme 1.0 Developing awareness of historical context			
Description: Students frequently discussed their learning of the historical context of Canada's relations with Indigenous peoples. Students noted that they began to recognize the complexity of the issues facing many Indigenous communities through discussions and class exercises on housing. In an effort to process or understand some of the topics of discussion, some students made parallels to other historical and contemporary events where they felt injustices were perpetrated on a group of people.			
Sub-themes	1.1 Recognition of Complexity	1.2 Abstracting to other historical or contemporary events	
Excerpts: "Through grade school I learned very little about Indigenous communities and the history of the first peoples in Canada." "During the blanket exercise, learning the chronical order of events has brought to light how intentional everything the Federal government did and how systematic racism carries through generations." "By looking into the past, it helps us understand the colonial policies and practices that unfolded throughout the years that have tremendously impacted the lives of the Indigenous peoples." "The housing problem and consequently the healthcare problem is a cycle that needs to be addressed together and uniquely for each community." "I try to resist comparing [to the] holocaust, but as I hear more and more details about what has happened, it is hard for me not to."			
Theme 2.0 Identifying bias in self and others			
Description: Students were identifying previously held beliefs and traditions, reflecting on origins of personal bias, and recognizing bias in others as they discussed the learned history with other peers and family members.			
Sub-theme	2.1 Identifying personal bias	2.1 Contemplating source of bias	2.2 Identifying bias in others
Excerpts: "I was also enlightened to the fact that in the past I really thought that it was we can do this for them. Two things came to me these last three weeks about that. Why do I use the word them? Maybe it is an learned bias that I have subconsciously." "I feel like I learned more in the past few sessions in this class about Indigenous Peoples than I have in all my years of schooling. It really makes me re-evaluate my own challenges when I feel that I am being faced with something that either doesn't seem fair or makes me upset." "I now look back on what I had been told about Indigenous peoples and what I had heard on the news, etc. and realize how skewed that perspective was, because I was only hearing one side of the story."			

"I now look back on what I had been told about Indigenous peoples and what I had heard on the news, etc. and realize how skewed that perspective was, because I was only hearing one side of the story."

Theme 3.0 Struggling with difficult emotions

Description: Students expressed an array of feelings as they learned about and processed the historical context of Canada's relationship with Indigenous peoples. Many students expressed sadness and guilt. Some students exhibited distancing behaviours from the actions of the Canadian Government and Church organizations by noting they did not commit the atrocities, nor did their families to their knowledge. Some students expressed confusion at the actions of the Government and the purpose of assimilation. Some students expressed empathy with the facilitators for the heavy burden they bear in teaching others this history, and gratitude for the facilitators in taking the time to educate them.

Sub-theme	3.1 Sadness and guilt	3.3 Distancing	3.4 Confusion	3.5 Empathy	3.6 Gratitude

Excerpts:

"That seminar was extremely heavy and emotional for me, and I can't even imagine the toll it must take to be the one presenting."

"I know I am not the only one in our class who, over the last couple weeks has felt an overwhelming sense of sadness and shock from what we have learned in this class."

"it made me realize just how much Indigenous people have to give of themselves in order to teach non-Indigenous people about the extra weight that they carry."

"I am so grateful to them for the good work that they [the facilitators of KAIROS and ICAT] are doing"

"Even though, to my knowledge, I am far removed from the people who committed the atrocities, I still feel a connection through the affiliation with the Catholic Church."

"I don't understand why the government was trying to assimilate the First Nations to the European lifestyle"

"Being a white male, I'm told that I have more privilege than most. What does that mean? I'm not exactly sure, but I'm reminded to check my privileges regularly. I'm told that I share some of the responsibility for colonialism. I'm told that the atrocities that were committed against the First Nations people are somehow a transgression that I am responsible for. How can this be? I am not a descendent of the people who committed these disgusting actions, and even if I was, how can anyone blame children for the actions of their parents?"

Theme 4.0 Commenting on instructional strategies.

Description: Students mentioned instructional methods and activities that they felt supported their learning. This included activities highlighting historical context such as the KAIROS Blanket exercise, the Cultural Acumen Training, the class exercises on historical housing policy, and assigned reading materials. Design thinking and systems thinking exercises were also mentioned, as well is face to face learning and circle discussions.

Theme 5.0 Exhibiting optimism for the future

Description: Discussion of hopes for the future of reconciliation, discussion of how students intend to use learning in their careers and lives.
Excerpts: " although terrible things have happened, we can continue to be hopeful" "I will hold onto the feeling that the corner of that blanket gave me and use it as inspiration to continue doing the work that I intend to do." "If we can have that many enthusiastic, passionate engineers working for change in First Nations communities then I really do believe that so much good can and will be done." "There were a lot of learning to take away from this and I hope to continue to educate myself about indigenous history through the rest of this class, future career, and life in general." "I plan to use this knowledge to take with me in future projects, interactions, and even when speaking to family members who may have their own opinions based on ill-informed prejudices."

3.6.2.2 Learning Journal 2 – Understanding Positionality

The phase of the second learning journal can be summarized as "*Understanding Positionality".* The time period for Learning Journal Two was in the fourth week of class. During this time, some students had connected with the partner communities and were trying to create initial problem frames and use design thinking tools to build empathy. Students had been introduced to design thinking and system thinking methods and mindsets such as the learner mindset, problem tree analysis, bias identification, engagement methods, research design, and interviewing. The students learning during this week of the course exhibited five key themes:

1. Self-reflection and awareness.
2. Positioning self within historical context.
3. Developing intrinsic motivations.
4. Forming empathy.
5. Commenting on how design and systems thinking will improve outcomes.

The coding manual for the thematic analysis of learning journal 2 is provided in Table 26, below.

Table 26 - Learning Journal 2 Coding Manual

Learning Journal 2: Coding manual			
Theme 1.0 Self Reflection and Awareness			
Description: In this phase of the course, the students were in a process of self-reflection and developing self-awareness in relation to emotional intelligence. Students commented on personal biases, reflected on the results of the EQ Inventory, set goals and actions to improve emotional intelligence, and reflected broadly on the purpose of empathy and emotional intelligence in engineering. Students abstracted the usefulness of emotional intelligence to their personal and professional lives.			
Sub-themes	1.1 Awareness of Personal Biases	1.2 Reflecting on EQ Inventory Results	1.3 Setting Goals and Actions
Excerpts: "I've been feeling a lot lately, and I think the challenge to unpack my own biases and the 'why' behind my thoughts and feelings is an appropriate one." "Doing the EQi testing and seeing my results was and still is quite interesting. I had expected some scores, like handling stressful situations to fall where they did, while others, I had not really realized that they would be so low. After discussing with the EQ coach, we set actions and goals to improve that low self-perception." "When we started discussing my results the parallels between my results on the [EQi2.0] quiz and my real-life experiences were uncanny. I think it was an awesome exercise and an experience I will remember for a long time." "Overall, I found the experience rewarding and informative and I really look forward to how I can progress my emotional intelligence throughout this course and my life. I am also hoping to use the information learned in my debrief conversation to become a better communicator and engineer."			
Theme 2.0 Positioning Self within historical context			
Description: Students were struggling with the emotions that came up around learning about Canada's treatment of Indigenous peoples. Students were continuing to process the historical context they were learning in class and had begin to attempt to try and position themselves within that context. This resulted in some struggling with terminology such as "settler", with the importance of their connection to land and place, and how we can move forward together. Many students became aware of and reflected on personal biases, thoughts, and their own traditions. In some cases students became hyper-aware of their biases, leading to challenges and fears of offending the partner communities.			
Sub-theme	2.1 Processing historical context	2.1 Struggling with positionality	2.3 Worring of offending
Excerpts: "Through learning about Indigenous peoples and their history, and through talking about different types of bias, I realize now that there is often a lot more going on than I realize. I am worried that I may not be quick enough to understand my own biases if I am unaware of them, and possibly that I might say something that I don't realize is offensive or rude because I don't understand the history or context of the situation fully."			

"I can feel the internal resistance when I hear about the concrete differences between First Nations people and non-Indigenous people in Canada. I am having a hard time accepting that we are different. I am having a hard time accepting that our histories are separate, that our connection to the land is different, and that our call as people to look after the Earth is different."

"As a Canadian citizen, I think it's important for me to support Indigenous Peoples on their journey of obtaining their rights and the land they rightfully own. We all need to work together to rectify all the mistakes that occurred in the past. All Canadian citizens have the duty to ensure every individual has equal rights and opportunities."

Theme 3.0 Developing intrinsic motivation

Description: Students personally connected to the projects they had chosen and their greater purpose. Students reflected on the deeper meaning of the projects – what it might mean to the community (empathy development). They also made connections to the projects and developed intrinsic motivations, including connection to important locations and past experiences, and consideration of future career commitments and trajectories.

Sub-theme	3.1 Contemplating greater purpose of projects to the Nation partners	3.2 Developing personal connections to projects

Excerpts:

"It is about revitalizing the culture and the language of the people that was meant to be extinguished"

"I understand this project is more than just a carving shed but rather a place for people to come together and share experiences and pass down knowledge to the next generations."

"Firstly, I really love that the carving shed will not only supply a major need to a specific artist within the community but that it will also provide cultural value as well. In addition, the location in Tofino provides some value and meaning to me personally. I'm super excited about this as it will provide me with an opportunity to have a positive impact on the community that has preserved and protected the land and ocean that I enjoy."

"This week in class we got to choose our projects and teams for throughout the course. I chose the [redacted] First Nation (FN) Creek rehabilitation project mostly because I was excited to work with [redacted] FN. At a previous co-op, I worked on a feasibility study/options report for them."

Theme 4.0 Forming Empathy

Description: Students mentioned instruction strategies that contributed to their learning, this included mention of field-trips, EQi2.0 inventories, empathy building experiences, participatory learning , sequencing of lessons, and design and systems thinking tools (affinity mapping, empathy mapping, design mindset, problem framing, problem tree analysis, semi-structured interviews, user-personas, etc). The activities students noted as significant in this phase were primarily about understanding context, and developing empathy. The sub-categories included experiences leading to empathy formation, tools to understand context, and tools to understand people.

Sub-theme	4.1 Experiences to develop empathy	4.2 Tools to develop deeper empathy	4.3 Tools to understand complexity

Excerpt:
"The KAIROS Blanket Exercise really resonated with me for this reason. It was such a cool experience, to have so many people, with so many different backgrounds, come together and collectively listen and empathize with someone who many of us had never met before."

"I made a user persona from the community of Tsawout's perspective. It wasn't until Eric pointed it out that I realized I assumed all generations within a community have the same perspective. Not only does each generation within a community have a different need/want, each First Nations community across Canada have a different need/want. Each community deserves infrastructure that meets their specific needs/cultural behaviour."

"Both groups are bringing different knowledge to the table, and both ways of knowing are important to the project. Connecting these two ways of knowing will be difficult, but I believe it will result in a much more impactful project outcome."

"Last week during class my community project group performed the Problem Tree Analysis. It was a great exercise and was quite eye-opening in allowing us to see the root causes, and effects that result from poor housing within Indigenous communities. It was clear from the exercise that certain causes were also effects thus resulting in a cyclical relationship."

"The in-class exercise with the sticky notes further enhanced my understanding of the systems thinking approach but with respect to Indigenous history."

Theme 5.0 How Design and Systems Thinking will improve project outcomes

Description: Students discussed the ways in which they noted that design and systems thinking has the potential to improve their project outcomes and engineering practice. This included categories such as: asking better questions, seeing complexity, deeper understanding of context, incorporating diverse perspectives, a better understanding of the need for social competence, and personal growth.

Sub-theme	5.1 Asking better questions	5.2 Seeing complexity	5.3 Developing a deeper understanding of context	5.4 Incorporating diverse perspectives	5.5 Personal growth

Excerpts:
"I wonder how many times people have worked on projects for indigenous communities and not understood exactly what the community wanted because they never actually got to interact with them… and how many problems this could have solved."

"I gave me a better understanding to the idea that once a system is put into place, it's there to stay and very hard to change. Brainstorming potential good and bad outcomes that may come of your actions, or better yet, just straight up asking what is needed rather than assuming, is a way to try and break these cycles. Listening before acting in projects and situations can make all the difference"

"As a professional engineer, these types of problems require different types of thinking, and trial and error is most certainly not an option."

"Both groups are bringing different knowledge to the table, and both ways of knowing are important to the project. Connecting these two ways of knowing will be difficult, but I believe it will result in a much more impactful project outcome."

"I have gotten so much more out of this course than all of my other courses, and I think it can mostly be attributed to the fact that I am being challenged in ways that most other engineering courses do not. I find engineering can be 'challenging,' but typically in terms of the logic, mathematics and analytical problem solving. This course has been great because I feel that I have learned so much more than I ever expected to learn about Indigenous people and their history in this country, but I have also learned lots about emotional intelligence and empathy – skills that the classic engineering courses typically do not challenge at all."

3.6.2.3 Learning Journal 3 – "Moving into Action"

The phase of the third learning journal can be summarized as *"Moving into Action"*. The time period for Learning Journal three was during the 5th week of class. During this time, the students had started to engage with the partner communities, attend field trips to partner communities, and create initial problem frames. Students had been introduced to design and systems thinking methods and mindsets such as the learner mindset, problem tree analysis, bias identification, engagement methods, research design, and interviewing. The students' learning during this week was similar to that of Learning Journal Two. It exhibited five key themes:

1. Processing of historical context.
2. Self-reflection and awareness.
3. Developing intrinsic motivations.
4. Engaging with Communities.
5. Gaining first hand experience.

The coding manual for learning journal three is provided in Table 27, below.

Table 27 - Learning Journal 3 Coding Manual

Learning Journal 3: Coding manual			
Theme 1.0 Continued Processing of Historical Context			
Definition: In this phase of the course, the students continued to process Canada's history with Indigenous peoples. Some students had moved from reflecting on the past events to reflecting on the deeper implications to Canada's reputation, the hypocrisy of Canada's portrayal as a peace-keeper and their own conceptualization of Canada as a country. Some students expressed dissonance from receiving the benefits of living in Canada while many Indigenous communities are suffering. Some of the students gained first had experience with the complexity and inefficacy of government funding systems for infrastructure in Indigenous communities.			
Sub-themes	1.1 Reflecting on Canada's Image	1.2 Commenting on dissonance	1.3 Developing deeper understanding of government policy
Excerpts: "I will always appreciate the country that has allowed me to pursue a higher education and comfortably live within its borders, reaping the benefits of universal healthcare and affordable education. However, through the short period of learning that I have had in this course I have realized that there is a hypocrisy in the core values of this country and how it portrays itself to the world." "This course has opened my eyes to the plight of Indigenous people in Canada and the history of how settler Canadians have treated First Nations lands and their people." "Reflecting on my own thoughts I highly sympathize with nations who require this "approval" from a government who will not even listen to exactly what is required. It reminds me of the idea of never actually having independence or freedom to do what you want to do." "Any project in an indigenous community seems like a much more complicated project than any other typically engineering project because you also must deal with the complexity of issues that arise from a lack of planning from the early stages of the community planning and the limited funding that has gone into maintaining and improving the community."			
Theme 2.0 Self-Reflection and awareness			
Definition: In this phase of the course, continued to process information, reflect and develop deeper self awareness. Students identified and contemplated their personal biases and also noticed bias in others such as team mates. Some students moved beyond simple identification of bias, to contemplating ways that bias might impact their projects and how to mitigate its effects. Other students struggled with positioning themselves within the context and rejected the idea of "labels" used to categorize Ones experiences and world-views. Students continued to reflect on the results of the EQ Inventory.			
Sub-theme	2.1 Identifying Bias	2.1 Struggling with positionality	2.3 Considering ways to mitigate bias
Excerpts:			

"However, it seems that it can be a revolving door of thought – I think one thing, then start to consider why I think it, and then based on my own evaluation of why I think what I think, I can then consider whether my thought had a bias and whether that bias is limiting my ability to see reality for what it really is. My issue is that reality is subjective; the way that I view the world is different than the way that some else does – and that's the whole reason we need to communicate."

"I believe that a failure of mine in my previous journal entries has been a lack of self-reflection and introspective thinking, so I will focus on some of those thoughts."

"Initial biases of anchoring and availability heuristic I feel as though I can mitigate through the background knowledge and system/problem framing skills. In terms of the 'framing effect', I am guilty of looking at a design problem solely from the paper in front of me, but I feel that I know the importance of truly understanding a problem, and not running off with the first problem statement that is given to me."

"After receiving my EQ results, I have identified reality testing, empathy and social responsibility as emotional intelligence skills that I can develop throughout this semester."

Theme 3.0 Developing intrinsic motivation

Definition: Students connected to the projects and their greater purpose. Students reflected on the deeper meaning of the projects – what it might mean to the community (empathy development). They also personally connected to the projects and developed intrinsic motivations. This included important locations, past experiences, and future career commitments and trajectories.

Sub-theme	3.1 Contemplating greater purpose of projects to the Nation partners	3.2 Developing personal connections to projects	3.3 Abstracting to future career

Excerpts:

The basic idea for our project is to design a sports field. But really the basis of the project is to create a second home for the youth, adults and even other non-Indigenous community members. I personally have so many fond memories of the baseball and soccer fields where I grew up playing sports. My teammates were my second family, my friends who I spent every summer with and many of those friendships lasting 20 years or more.

After the content and activities, I feel as though strong connections have been tied now from the issues facing Indigenous communities and people to the effects that our future careers can have. As someone going into the field in British Columbia, every project I do will have sometimes unforeseen downstream effects, negative of which disproportionately impact First Nations communities.

Theme 4.0 Engaging with Communities

Definition: Students had entered into engagement with the partner communities and had employed design and systems thinking tools they had been learning in class. Students gathered client needs using

semi-structured interviews and developed User Personas to try and gain a deeper sense of connection to the people in the communities they were serving.			
Sub-theme	4.1 Engaging with User Groups	4.2 Gathering client needs	4.3 Using Design Thinking Tools
Excerpts: "For my learning journal this week, I want to reflect on visiting the community for a community engagement meeting regarding the creek. I felt honoured to be invited as a guest to the community and was excited to learn more about the community member's thoughts and concerns about the Creek restoration project" "This morning our group had our project kick off meeting with our community representative from [redacted] First Nation" "This week our group had our initial meeting with the representative from the [redacted] Nation that we will be working with for our design project. I was very excited for the meeting to be able to meet someone from the community, see the reserve and learn more about the project." "The empathy map/user profile exercise was very interesting to work through in our groups. I think that my mind tends to think in this type of way – I'm often empathetically curious– but I have difficulty saying these things out loud and writing them on paper." "I volunteered to do the interviewing, as we didn't want to overwhelm him with too many people asking questions at once. I wanted to practice my interview skills, as well as have a chance to connect with him."			
Theme 5.0 Key- Gaining first-hand experience			
Definition: Having entered into the engagement process with the partner communities, students were being faced with the complexities and emotions surrounding their projects. Students were coming face-to-face with the real-world realities of the history they had been learning of to this point in the course. This included hearing from community members about the way in which infrastructure is developed and planned in their communities, and seeing the state of infrastructure on reserve. Students noted cultural differences between Indigenous and non-Indigenous communities, attitudes of Indigenous Nation members towards professionals, and the attitudes of professionals towards community members. Students commented on the deep knowledge that elders and community members held. Students often commented on key-takeaways they had learned from the community members, or reflecting on the challenges they encountered when implementing the engagement tools they had learned about and practiced in class.			
Sub-theme	5.1 What stood out in engagement	5.2 Takeaways from tools and methods	
Excerpts: "Driving onto the reserve I felt like we left Canada. Compared to the cute main street of Sidney that is around the corner, the little part of the reserve I got to see was certainty different."			

"I have never been to a First Nations community engagement session before and it was interesting to see the lack of trust the elders had towards the [professional] engineering solutions. It was sad to hear the stories of how infrastructure and colonization has affected this community."

"Another takeaway for me was how committed to community all people in attendance were. This is vastly different to my experiences living in my community back home in Calgary. You may know your neighbors and have friendly conversations with them, but it is nowhere near how tight-knit I saw this community to be."

"A few of the messages the elders said that have stuck with me are; "every year something is taken from us", "I feel like [this] isn't even our reserve anymore", "everyone is in their separate corners, no-one is together anymore", "there is no-where to go". Over years of not being consulted about the projects on the reserve and slowly seeing the creek's ecology fade I can feel their frustration."

"There were so many aspects of the carving process that we had never thought of, or heard of, and hearing them from Joe will add so much meaning to the outcome of our project."

"In the engineering projects I've been a part of in the past, the work focused heavily of the technical aspects, meaning I haven't had much experience doing engineering work from the social and cultural perspective. In this project, the social and cultural aspects are just as important as the technical side, so hearing directly from people in the community was a great learning experience on how to frame this project moving forward"

"I found many of the systems framing, Indigenous collaborative design, and bias type reflecting to be very tangible for self-reflection and considering future design projects."

"seeing how we were right and wrong also helped with understanding how those empathy maps and abstract laddering methods we did really helped."

3.6.2.4 Learning Journal 4 – Continued Growth

The phase of the fourth learning journal can be summarized as "continued growth". The time period for Learning Journal Four was during the 6th week of class. During this time, the students engaged with partner communities, conducted practice interviews, interviewed community partner, and gathered and analyzed qualitative data to determine if they needed to re-frame their projects. The students learning within this phase was categorized by four (4) themes:

1. Communication and perspective taking.
2. Experiencing complexity and forming problem frames.
1. Engaging with communities.

2. Gaining firsthand experience.

The coding manual for learning journal 4 is provided in Table 28, below.

Table 28 - Learning journal 4 Coding Manual

Learning Journal 4: Coding manual			
Theme 1.0 Communication and Perspective Taking			
Definition: Many students commented on their experiences with engagement through interviews. They covered a wide range of sub-topics relating to communication and shifting perspectives, including lessons learned in the practice "tell me about home" interviews, overcoming fears, developing active listening, and their experience with project interviews. They noted how interviews can challenge biases and create greater appreciation for diverse world-views. They also noted the importance of a learner mindset, remaining flexible, humble and adaptable, and not leading interviewees in their answers.			
Sub-themes	1.1 Shifting Perspectives	1.2 Remaining flexible, and adaptable	1.3 Importance of not leading interviewees
Excerpts: "This week we worked on Interviewing and boy was I bad at it." "This exercise was very interesting to me because I could see just how much my perspective on "what home means" changed throughout the exercise. This highlights how important it is to have proper interviewing skills within First Nation Communities, because with proper interviewing techniques you'll be able to get in-depth and comprehensive answers to your questions and have your perspective change through this." "Previously I have been afraid of asking the wrong questions or unintentionally offending someone. … it's better to be not afraid of saying the wrong thing and to just acknowledge and understand where you have gone wrong when and if you do slip up." "think it all ties back into understanding that as engineers when it comes to community issues, we are not the experts and that we need to be open and considerate to whatever community members are trying to express because they are the actual experts."			
Theme 2.0 Experiencing and forming problem frames			
Definition: Students commented on how systemic complexity changes the way in which a problem is framed. They noted the need to recognize interconnections, and consider the broader impacts of designs on communities. Students noted deficiencies in a standard approach of problem definition taught to them in their education. They highlighted the importance of design and systems thinking methods on creating insight based problem frames.			
Sub-theme	2.1 Recognizing complexity	2.1 Insight based problem framing	
Excerpts: "I found that moving information into 'upstream' and 'downstream' impacts provided a clear visual problem framing… it is clear how these wicked problems exacerbate and feed into adjacent issues of			

poverty and the deterioration of cultural practices like clam harvesting… Personally, I feel as though I did not understand many of the downstream impacts or their
gravity occurring from issues like climate change, pollution, and government policy."

"These issues impacting the community has helped frame how complicated and far reaching they are and how important it is to seek a full problem frame; not only to obtain the technical problem, but to obtain get the emotional and cultural problem through their perspective through this framing and speaking with them."

"The human-centered approach to framing problems is obviously new to me. It is clear upon writing the first project submission how such an approach feels a lot more appropriate. Even the general terminology used before, when placed in this context, felt inappropriate."

Theme 3.0 Reflection on ethical responsibilities

Definition: Students connected themes and experiences from class to professional aspirations and ethical obligations as an engineer. Students reflected on the sometimes conflicting relationship between a community's desires and actions, and professional ethical responsibilities.

Excerpts:
"I believe in the rights and title of Aboriginal Peoples to fish and harvest in their waters, but as an engineer, I may be held accountable for a design that may harm someone, such as if someone were to consume a clam from the garden I helped design."

Theme 4.0 Self Awareness and Personal Growth

Definition: Students continued to develop self-awareness through engagement with class activities. Writings focused on introspection, self-improvement, and metacognition. Students commented on bias identification, developing a growth / learner mindset, the development of an appreciation of diverse world-views, and processing and moving away from feelings of guilt about Canada's past.

Sub-theme	4.1 Self Awareness	4.2 Bias Identification	4.3 Mindset

Excerpts:
"My interview questions, though I did not realize at the time, were very biased towards my own sense of home. I created the questions based on how I expected them to be answered. What I didn't realize is how different some of the answers would be from my own."

"I think that my interpretation of what others say can often be clouded by my own experiences because I think more people are more like me than they actually are."

"Reflecting on my own bias: I get to say all this from a place of complete food security. I have never been in a position where I can't afford to feed myself. I have come to understand through meetings with [the community] that many community members are food insecure. They can't or don't want to buy things from the grocery store. They want to go out to nature's refrigerator (i.e. the clam garden) and harvest their food for themselves, without having to pay."

"Walking into a First Nations reserve engineers are not the expert, the people who have lived there for years are."

"Becoming comfortable with the idea of moving from guilt to acceptance and understanding would be the next logical step in being able to work towards effectively ensuring my decisions are causing actions which are moving to work towards supporting an environment where my actions can allow a difference to be made."

3.6.3 Final Reflection Analysis

The students produced a final reflective paper, commenting on changes in their emotional intelligence profiles and providing personal insights into the change. Students were asked to discuss what they felt had the greatest impact in their emotional intelligence. This was used to identify which instructional strategies and course experiences were most beneficial and provided credibility to the hypothesis that the course led to the change in their emotional intelligence profiles. The research question for this stage of the analysis was: *" To what are students attributing their changes in emotional intelligence?".*

The students' final reflections were analyzed looking for topics that students noted as impactful to the development of their emotional intelligence. The codes were sorted into the categories and sub-categories of emotional intelligence. Table 29 outlines which activities can be attributed to the development of target areas of emotional intelligence. It is interesting to note that while the course design did not target all areas of emotional intelligence, across the reflective writings, the students did discuss aspects of each category. This shows that drawing greater awareness to emotional intelligence broadly can be a catalyst for self-improvement. Students independently reflected on their results with their EQi2.0 coaches, identified strengths and weaknesses, and created strategies for self-improvement in areas of meaning to them.

Table 29 - Final Reflection Emotional Intelligence Themes and Activities

Category	Subcategory	Activities	Excerpts
EQ- Overall	N/A	The course in general	"I do believe overall my awareness on empathy has increased drastically. Before this class and the EQI, empathy was never considered a skill but through this course and speaking with the EQI professional, I became aware of its importance."
		Taking the EQi2.0 inventory	"The EQi test was very interesting and eye opening because it highlighted where I am at with respect to each of the categories of emotional intelligence."
Interpersonal	Empathy	Active Listening	"I didn't intentionally work on this skill, but listening to others and trying to improve my emotional expression by listening to my teammates may have had an impact on this score."
		Being aware of empathy	"I do believe overall my awareness on empathy has increased drastically. Before this class and the EQI, empathy was never considered a skill but through this course and speaking with the EQI professional, I became aware of its importance."
		Experiential Activities	"With the beginning of the course being more focused on understanding the history of the First Nations peoples, it set a solid basis for me to be able to sympathize and empathize about the hardships and injustice that they faced through history. In a personal sense, I experienced my largest change in emotion near the beginning of the course with the blanket exercise."

		Developing interpersonal relationships	"My score for empathy increased significantly, which I think may have been a result of my development of interpersonal relationships."
		Field trips	"Throughout the class project I was able to improve my biases when working with the nation and was honored to be invited with my team for a stream walk on their property."
		Identifying Biases	"… the main growth I feel was through learning about the different types of biases that I was previously unaware of, including how to identify and mitigate them. These included how I see the world through the largely western view that I was raised in and the impacts that language may have on someone."
		Observing Classmates	"Seeing my classmates tackle these issues and grow because of it helped me to have more empathy towards those who haven't started on their reconciliation journeys yet."
		Problem Framing	"Problem framing exercises in class and the lecture material all helped improve on identifying my biases and recognizing the difficulties indigenous communities have."
		Reflective exercises	"The reflections and learnings throughout this term have allowed me to dig deeper into the biases and preconceptions I had regarding working with First Nation communities."
		Setting Goals / Working with a Coach	"In discussion with my coach, I have developed a plan to improve both. For empathy, I have committed to showing empathy on at least ten occasions between February and April to build the habit of showing empathy"

	Interpersonal	Developing Listening Skills	"Additionally, as a result of these assessments, I have been able to improve my listening skills which have largely helped me to be open learning diverse ideas which can be presented by other parties and work better on teams, which is a very crucial element of the career that I am about to go into."
		EQ Exercise	
		Field Trips	
		Interviewing Experience	
		Making effort to build networks	"By the end of the semester, I grew my relationships in all of my classes from strangers to acquaintances, and even to friends with many people. Not only did I improve my relationships with my classmates, but I had many opportunities to grow my relationships with professors, By the end of the semester, I grew my relationships in all of my classes from strangers to acquaintances, and even to friends with many people. Not only did I improve my relationships with my classmates, but I had many opportunities to grow my relationships with professors"
		Mentorship and feedback	
	Social Responsibility	Experiential Activities	"I'm so glad I've had the opportunity to learn about some of the complex issues faced by First Nation communities in Canada today, and the ways I can contribute in the journey towards reconciliation."
		Group Discussions	"I have had the opportunity to participate in weekly discussion posts regarding many humanitarian issues that impact First Nations."
		Guest Presentations	"I feel like I was given the tools to make a difference with my degree in my future job, where before this semester I didn't have a clue what that job would look like. I was also exposed to so many Indigenous people doing amazing things. Seeing
		Identifying Mentors	

			Tina do the blanket exercise, Rob teaching the cultural acumen seminar, and Eli and his son doing all of the work with the ISAAK OLAM foundation was inspiring."
		Real World Projects	"I feel like I have significantly contributed to the real project and attended to one of the main concerns the nation has"
		Self reflection	"Since my midterm reflection my definition of social responsibility has changed. Before I was thinking of social responsibility as something big, hence scoring very low in my initial IEQ report, but in reality I do a lot of small scale actions every day to create a positive impact on society."
		Setting Goals	"A short-term social responsibility goal I have is to present a guest lecture to a physics class at the high school I attended."
Self Perception	Emotional Self Awareness	Being aware of EQ	"Simply being aware of these emotional intelligence indicators allowed me to recognize patterns in my own habits and behaviours in different situations as I progressed through this busy school term. If anything, it gave me more self awareness, which I think I needed."
		Self Reflection	"Understanding who I am, how I want to show up in the world, what are my top values, are all things that have become more clear in the last few months as I have been reflecting on what this new chapter of life should be."

		Taking the EQ inventory	"The EQI emotional intelligence (EI) report has allowed insights into how I perceive, control, and reflect on my emotions. By undertaking this exercise, I was able to quantify my emotional intelligence, and create a methodical approach to improvements I can make in certain areas."
		Working in groups	"I have improved my listening skills and take time to appreciate other people's aspects and views. One of the biggest lessons was learning that I am not always right and learning how to compromise when there are multiple ideas shared especially in work groups"
		Working with Coaches	"I believe that the EQi coaching over the two meetings gave me more insight into what these emotional intelligence (EI) scores mean, helping me understand what aspects of my life I can reflect on and improve during the semester"
		Working with Community	"The emotional-based learnings came not only from taking the EQi test and having the debrief session with an emotional intelligence coach, but from the meetings we had with our community representatives for the term project for this course."
	Self-Actualization	Setting and Review Goals	"There were large growths in two of my 'target' areas of the SMART goals, self-regard and most of all, self-actualization"

	Self-Regard	Setting Goals / Working with a Coach	"My goal stated in the midterm reflection was to improve my self-confidence by preparing a strong resume and linkedin presence. I have prepared a core cover letter and resume that I am proud of and put a lot of time into. While writing my resume and cover letter, I was reminded by all the things I DO KNOW, rather than in my head focusing on all the things I DON'T KNOW"
		Taking the EQi2.0 inventory	"Through these assessments, I have developed a strong sense of my strengths and limitations with my self-confidence setting me apart as someone with self-respect."
		Working in a team	"I also feel that I gained some self-awareness and was able to recognize my own position in a group and better understand my own role within the team."
Self Expression	Assertiveness	EQ Process / Working with a coach	"Previously, I would not be able to express my needs and wants in all types of relationships however, through this emotional intelligence exercise, I learnt great techniques to communicate especially in times of conflict."

	Emotional Expression	Learning journals	"The learning journals were a great opportunity to actively reflect and interact with the material I learned throughout the semester. Prior to this class I had never conducted in-depth reflective exercises like these learning journals in my university career, so I was very excited to have this opportunity. The chance to reflect on the learnings deepened the knowledge I had and help to identify any further questions I had on the subjects. The sections below outline the learning journey I had through each of my journals."
Decision Making	Impulse Control	Working with Mentors	"To also assist with my decision making, I have also taken a strategy to seek expert advice either from my peers or experienced persons especially when I am unable to make an unbiased / impulse filled decision which might later on be regretful."
	Reality Testing	Class Project and DT Methods	"The next skill was reality testing in which my initial score was 92 and after the second test it is now 100. This improvement can be directly related to the class project. Problem framing exercises in class and the lecture material all helped improve on identifying my biases and recognizing the difficulties indigenous communities have."
		Instructors	"I believe [the instructors] did a great job at identifying where engineers have aloud their biases to effect how they work with indigenous communities and thus resulted in the increase in my score [in reality testing]."

Stress Management	Flexibility	Setting Goals	"I have forced myself to experience new activities such as changing my gym and my soccer team. I believe that with these two major changes to my daily routine, I have become more flexible in general and more comfortable with changes to my lifestyle or how I do things. This is reflected in my second EQI assessment where my flexibility score has increased"
	Stress Tolerance	Mentorship and Coaching	"I have experienced immense stress, probably the most amount of stress that I have ever experienced in my life. Despite the presence of this stress throughout the entire term, I am proud ot say I have developed relatively good techniques to manage it. One of the best stress management techniques I have developed especially because of these EQi assessments s to plan and prioritise deliverables in order of due dates, talk about it with peers / counsellors and distracting oneself with activities that can boost my mood/ attitude."

Presented in a more general form, these are the themes of activities that the students noted as making an impact on their emotional intelligence throughout the semester.

Table 30 - Final Reflect Themes and Activities

Theme	**Activities**
Developing Social and Cultural Awareness	Including social competencies in engineering discourse
	Becoming aware of biases
	Appreciating diverse worldviews
	Cultural acumen training
	Becoming aware of emotional intelligence
	Experiential learning
Building Relationships and Collaboration	Developing interpersonal relationships
	Group discussions
	Identifying mentors
	Observing classmates
	Working in person
	Working with communities
	Working with team members
Experiential and Applied Learning	Field trips
	Ethnographic experiences
	The final project – working on real-world projects
	Making a real difference
	Experiential activities
Problem-Solving and Critical Thinking	Implementing DT and ST tools
	Problem-framing exercises
	Learning to reframe the challenge
	Instructional strategies
Self-Reflection and Personal Growth	Reflective learning journal activities
	Reframing perspectives to improve self-perception
	Setting and reviewing goals
	Undertaking EQi 2.0 assessments
	Creating a better understanding of strengths and weaknesses through coaching conversations
	Developing a deeper understanding of self through the EQi inventory process
Communication and Leadership Development	Learning active listening skills
	EQi2.0 coaching and inventories
	Identifying mentors
	Setting and revisiting goals

3.6.4 Discussion of Qualitative Analysis

Frequently, the qualitative writings showed that the students attributed the positive changes in their emotional intelligence to their experiences in the course. In particular, students engaged in many activities leading to empathy development such as the Indigenous cultural acumen training, KAIROS Blanket Exercise, direct engagement with community members, and direct engagement with team members.

In addition to the data excerpts in the tables above, quotes from the data linking course experiences to the changes in EI are provided below:

Student 4, who exhibited a 5-point increase in empathy, an 11-point increase in social responsibility, an 18-point increase in self-expression and an overall increase in emotional intelligence of 10.8 points stated: *"I have grown more and learned more important skills than any course to date and I can't imagine any in the future will help me grow more as a human then this one. I am incredibly grateful to be taking so much out of this course and while still a work in progress I am really happy to be working on my relationships, biases, empathy and interactions with Indigenous communities I will have in the future, something I would not have thought about or worked on without this course."* This student also noted the importance of engaging with senior engineers on a qualitative research trip, showing the importance of encouraging professional socialization with engineering practitioners.

Student 2, who showed large changes in both empathy and social responsibility stated: *" I didn't intentionally work on [empathy], but listening to others and trying to improve my emotional expression by listening to my teammates may have had an impact on this score. Opportunities to improve my empathy were offered throughout the semester, like during the KAIROS blanket exercise, or during the cultural acumen training…Further, both opportunities allowed me to see how my classmates felt about the situation and allowed me to feel slightly more forgiving when someone didn't know something. It*

isn't easy to educate yourself on these types of topics; they can be very heavy and difficult to really understand. Seeing my classmates tackle these issues and grow because of it helped me to have more empathy towards those who haven't started on their reconciliation journeys yet."

Student 21 who showed a 22-point increase in empathy and a 21.8-point increase in emotional intelligence stated: *" I had opportunities to partake in unique experiences that have contributed to changes in my emotional intelligence. These experiences have positively influenced my emotional intelligence and have helped me develop personally and professionally."* This student identified the qualitative research gathering experience as a significant contributor to changes in their emotional intelligence. They stated: *"A course experience that has significantly contributed to the changes in my results was our site visit to a potential clam garden location... During this beach visit, we had the opportunity to connect with the community members and understand the traditional and cultural significance behind the clam garden project. It was amazing to see everyone from the community, including elders and children, come together to help with the project. As an outsider, this helped me see first-hand how vital the clam garden was to the Nation, as they could pass down the traditional harvesting practices to the future generation."* In addition, they expressed that the course experiences helped them to identify personal biases and misconceptions about Indigenous culture and rights – providing an avenue to appreciate diverse worldviews.

Student 8, who exhibited a 19-point increase in the sub-category of Social responsibility contributed this to a "re-framing" of their thoughts on what it means to be socially responsible. This student shifted thinking about social responsibility as "something big" to every day small tasks and actions that create a positive impact on society – things like recycling, giving a seat up on the bus, paying taxes, contributing quality work to team projects, etc. Although they shifted their framing on social responsibility, they also did not shy away from bigger social responsibility goals such as using their engineering degree in humanitarian contexts. This student exhibited a decrease in emotional intelligence overall, primarily in

self-perception, optimism, and interpersonal relationships. This student attributed these decreases to their stress levels and burnout. This supports to criticism that the EQ-i inventory can be manipulated based on the participant's mood.

Student 7 who exhibited a 5-point decrease in empathy noted that they were actively trying to be more empathetic in life and had even made this a goal in their personal development plans. As such, they were surprised by the small dip in empathy in their EQ-I profile, stating: *"With practice, I believe that I am becoming more comfortable showing empathy while still holding people accountable for their responsibilities. Surprisingly, although I feel I have progressed on this aspect, my second EQI assessment shows a slight decrease in my empathy score."*

Student 25 attributed some of the changes to emotional intelligence to the cultivation of an environment that allowed difficult questions to be asked without judgement: "I'm thankful that [the instructors] created such an open atmosphere. I asked early on if there were any wrong questions that could be asked and was relieved to hear that there weren't – instead, this course was the place to ask those questions." Additionally, this student cited the KAIROS blanket exercise and other class experiences as a direct means of helping them to understand diverse perspectives: *"I had a lot of great experiences over the course of the semester. I especially enjoyed the KAIROS Blanket Exercise and the conversations that came from it. It was a valuable exercise that helped me better understand the history of First Nations people in Canada from their perspectives."*

3.6.4.1 Examining Potential Outliers: Student 21

Student 21 consistently exhibited outsized increases in the categories and sub-categories of emotional intelligence analyzed in this study. Using the statistical method of determining outliers (1.5 IQR method), this student was flagged as an outlier in interpersonal, stress management, and empathy. However, the sample size in the data is not large enough to determine if this is indeed an outlier on a normal

distribution, or just a data point that aligns with the tail end of the normal distribution. It is possible that these data points are not outliers, and would fit the normal distribution if a greater number of data points were collected. This is a limitation of the statistical methods and sample size of this study.

As such, this student's qualitative writings were analyzed in detail to determine if there is any qualitative validation that can be given to the results.

In learning journal 1, this student commented on the impact of the Cultural Acumen Training had on their awareness of Indigenous issues in Canada. They made the connection that understanding historical context is a foundational element of cross cultural literacy when working with Indigenous communities. They stated:

> *"This presentation presented Canada's colonial policies and practices from a different perspective. It has made me realize the importance of understanding the colonial policies and practices to work with Indigenous peoples effectively."*

Even in this first learning journal, this student commented on their social responsibility commitments.

> *"It motivates me to make a change and help bring justice to all the Indigenous communities and everything they have had to sacrifice. As a future engineer, I want to work with Indigenous peoples on upcoming projects and provide support to the communities."*

This student deeply connected to the content of this course and the future impact it could make on their career, and on communities they will work with in the future.

In learning journal 2 this student reflected on their experiences with the KAIROS blanket exercise. This experience increased their awareness of historical context, highlighted personal biases and positionality, facilitated the formation of empathy. The student states:

> *"The KAIROS Blanket Exercise made me realize that Indigenous Peoples have been through many hardships and are continuing to fight this battle against the Canadian Government. I come from a family of immigrants that moved to Canada looking for more opportunities. Therefore, I had this image that Canada was a country with peace, safety, equal opportunities and rights for e*very individual. However, Canada's history with Indigenous Peoples does not portray the same image… *This exercise has also made me realize how privileged I am to have this sense of safety and freedom. Before I experienced this exercise, I had a preconception that Canada was built upon equality, and they were working towards rectifying their past mistakes. However, this exercise has made me recognize that Canada still has a long way to go, and the issues still exist today."*

Empathy formation is evident when the student states:

> *"This exercise has helped me connect with the Indigenous communities emotionally and has helped build a strong foundation of knowledge."*

The student also further connects to the commitments to social responsibility made in learning journal 1:

> *"Getting the opportunity to be involved in this project is my first step in supporting the Indigenous communities."*

In learning journal 3 the student comments on design and systems thinking methodologies introduced in class, specifically in identifying complexity. This activity expanded their understanding of the contemporary issues stemming from inadequate and inappropriate government policy pertaining to Indigenous housing. This is evident when the student states:

> *"The systems thinking approach reveals the importance of understanding the inter-relationship of different events and items. It indicates that solutions require complex and reflective thinking*

because often, if solutions are not well thought out, they may result in more problems and issues. During class, we applied the systems thinking approach to Indigenous housings issues. We identified areas that may be causing the problem and the implication of the housing issues… We quickly realized the complexity of this issue. The overarching problem dates back to Canada's colonial policies and practices that initially forced Indigenous Peoples out of their lands and homes. We developed a diagram and web that showed the links between different events that have occurred and are resulting in housing issues... Based on design thinking, it is essential to design homes around the users and according to their needs and wants."

This learning module also helped the student to further confront personal biases, positionality, and misconceptions about Indigenous communities and government policy pertaining to Indigenous peoples:

"Before I took this class, I didn't have knowledge around Indigenous housing on reserve and the process. I had this perception that the government entirely funded Indigenous housing, and Indigenous Peoples owned the land and the house… As a first-generation Canadian, I am grateful that my parents had the opportunity to build their own home. They were fortunate to have support from the banks to receive a mortgage. As a result, my parents were given a chance to design their home based on our family's needs. The house was built according to the standards and equipped with necessary facilities. Unfortunately, that is not the same case for Indigenous communities trying to build their home. It is heart-breaking to hear that their living conditions are not equal to other individuals living in Canada and that their homes are causing health problems."

Learning journal 3 showed that the student was connecting on a deep and emotional level to the information they were learning, and the methodologies taught to provide solutions to wicked

challenges. This likely contributed to further developments in the categories of Interpersonal (empathy, and social responsibility), Self-perception (self-awareness). The act of undertaking the self-reflective journals likely contributed to the categories of self-expression (emotional expression) and self-perception (self-awareness).

In learning journal 4, Student 21 discusses their social responsibility to reconciliation in Canada and their commitments to furthering the Truth and Reconciliation Commission's 94 calls to action. They are optimistic in their outlook on reconciliation, stating:

> *"If all individuals work together with good faith and intentions, we can embark on a journey of mending relationships. A good starting place is to address and work towards fulfilling the 94 Calls to Action. I strongly believe that I can make a difference by working towards the following two principles:*
>
> *1. Educating others on Canada's colonial policies and practices and their impact on the Indigenous Peoples' culture, education, language, health, and economic opportunities.*
>
> *2. Supporting Indigenous communities to ensure their human rights and needs are recognized and met."*

In the final reflection, Student 21 focuses their discussion on the development of SMART goals throughout the semester to target three main EI subcategories –impulse control, emotional expression, and social responsibility. This student worked on the "clam garden" project and commented that a significant experience contributing to their changes in EI were the field trips to the clam garden location with members of the partner community. During this fieldtrip, the student had the opportunity to connect with community members and connect to the greater significance behind the clam garden project. They stated:

"During this beach visit, we had the opportunity to connect with the community members and understand the traditional and cultural significance behind the clam garden project. It was amazing to see everyone from the community, including elders and children, come together to help with the project. As an outsider, this helped me see first-hand how vital the clam garden was to the Nation, as they could pass down the traditional harvesting practices to the future generation. During our site visit we also had the opportunity to discuss project requirements and gain a deeper understanding of their needs and wants for the clam garden."

Student 21 noted that this experience not only helped them in the areas they focused their SMART goals on, but in EI overall:

"Firstly, it improved my emotional expression as I was able to express my thoughts and emotions to the community members. As a result, this allowed me to connect with the individuals and understand the hardships they may have gone through and how this project will help them tremendously in their lives. Secondly, this experience increased my social responsibility as I was able to support the Nation by volunteering my time to help prep the potential site for the clam garden. As a result, this will allow me to use my knowledge and skills to support Indigenous Peoples and communities in future projects. Lastly, this experience helped improve my impulse control. During the site visit with the Nation, I gained more knowledge on project specifics and the different requirements of the nation. This allowed me to be mindful and take more time to reflect on the inter-relationship of different items to understand the magnitude of the solution and all the people that may be impacted once the solution was determined. As a result, this will produce a more desirable and effective outcome for the project. Overall, this course experience helped me achieve my three SMART goals. Additionally, it strengthened my emotional intelligence not only in the three targeted categories: impulse control, emotional expression, and social responsibility but also in every other category."

Again this student commented on the impact of identifying biases and positionality within the course, and how that experience will impact their decision making and design process in the future:

> *"The course experiences have helped remove my biases and misconceptions about the Indigenous culture and rights. My biases and misconceptions formed due to the lack of knowledge around this sensitive topic. This is partly due to the lack of education I received in school and the lack of information available on Indigenous history… This experience has changed how I perceive biases and misconceptions. Indigenous history has taught me to view situations from a different perspective."*

The reflective writings of Student 21 demonstrated growth in various categories and sub-categories of EI throughout the course. Their writings showed advancements in the categories in interpersonal, stress-management, self-perception, self-expression, and decision making.

1. Self-Perception: Self-Awareness and Self-Actualization

From the first learning journal, Student 21 showed a great capacity for self-awareness. This self-awareness deepened in later writings, particularly in recognizing their own positionality, biases, and potential causes of biases. In addition, the student commented on the creation of three SMART goals at the start of the semester, that they had fulfilled by the end of the semester, leading to greater self-actualization.

2. Interpersonal: Empathy and Social Responsibility

A significant area of EI development was in empathy in social responsibility. The KAIROS blanket exercise facilitated empathy development and connection with historical context. he student explicitly stated that the exercise enabled them to connect emotionally with Indigenous peoples, a key marker of

empathy formation. Design and systems thinking exercises created a deeper awareness of contemporary struggles and systemic complexity.

Early in the course, student 21 expressed a commitment to social responsibility and reconciliation. Throughout the course the student was able to act on this commitment and fulfill a SMART goal established to develop this area.

3. Self-Expression: Emotional Expression

Student 21's emotional expression improved as demonstrated through their ability to articulate their thoughts and feelings on their learning through the learning journal exercises. In addition, the student noted that they were able to more freely communicate these feelings to community members.

4. Decision Making – Impulse Control

Student 21 noted that the improved ability to see systemic complexity would cause them to pause and consider *"inter-relationship of different items to understand the magnitude of the solution and all the people that may be impacted once the solution was determined."*

5. Stress Management – Optimism

Throughout the semester the student had reflected on their surprise and discomfort when learning about this historical context of Canada's relations with Indigenous peoples. By learning journal 4, Student 21 noted they felt optimistic about the path to reconciliation.

While Student 21's outsized increases in EI categories and subcategories were flagged as outliers using the 1.5IQR statistical method and on the Q-Q plots, the analysis of the qualitative data suggests that this result may not be an outlier. The qualitative writing demonstrated consistent changes across EI categories and sub-categories over the course of the semester. If additional data points were gathered, Student 21 may simply be on the tail end of the normal distribution. In terms of the quantitative data

analysis, this suggests that the data point should be kept in the statistical determination of significance, adding further validity to the result.

3.6.4.2 Examining Potential Outliers – Decreases in Emotional Intelligence

While the majority of students exhibited increases in overall emotional intelligence throughout the semester, there were two notable exceptions, Student 17 and Student 18. Both of these students showed a decrease in overall emotional intelligence and many of the composite categories and sub-categories. This warrants a closer investigation into the qualitative writings of these students to determine their overall sentiment towards the course experiences, and any comments on this result.

Student 17 exhibited an overall decreased in emotional intelligence through the semester as shown in Table 31.

Table 31 - Student 17 Quantitative Results

Category	Pre-Course	Post-Course
Empathy	83	86
Social responsibility	93	96
Emotional self-awareness	89	71
Self perception	106	98
Self-Expression	82	79
Interpersonal	93	94

Looking at this student's final reflection, their main takeaways from the course center around self-reflection, empathy, bias awareness, relationship building. This course greatly challenged their previously established linear approach to learning. The student noted that they *"think in very linear inputs and outputs"*. They noted that the learning structure they are familiar with is intended for the

student to *“develop a particular understanding and then display their understanding through a final exam”.* This course introduced a method of learning centered around what they noted as “reflection, empathy, and bias”, a deviation to from their previously established expectation of engineering courses and competencies.

This student noted that they feel the have developed a stronger sense of empathy: *“At the core of it, I have really developed a stronger sense of empathy, and realization of my own biases.”* The student acknowledged that their perspective on Indigenous issues was previously shaped by biases created in childhood. They state: *"Cognitive biases that I have shamefully previously held were through a lack of maturity, and lack of knowledge and empathy.*" This shows personal growth despite the self-reported decrease in emotional intelligence.

Despite a decrease in emotional expression, the student noted that the *“internal reflections done through the two EQi2.0 assessments and debriefs”* were an “*important part of [their] learning journey*”.

The student attributed the significant drop in their self-perception score to a decrease in their assertiveness. The student commented on this decrease:

“One factor that could have affected this decrease in score is the Dunning-Kruger effect. As I have begun to work on my assertiveness, and broaden my horizon on what low to high levels of assertion are, I have begun to realize that I am actually less assertive than I thought I was before this course”. This seems to be an accurate assessment. THe Dunning Kruger effect notes that an increase in awareness of one’s base level of understanding (or lack there of) results in a decrease in confidence.

This student also noted that they struggled interpreting their EQi2.0 results – seeing low scores as negative, where the coach noted that low-scores are not necessarily a negative. This suggest that the student was becoming more self-aware and was experiencing doubt or disappointment with their results, perhaps leading to a decrease in self-regard (a sub-category of the self-perception composite).

Student 18 also showed a decrease in overall EQ, as shown in Table 32 below:

Table 32 - Student 18 Quantitative Results

Category	Pre-Course	Post-Course
Empathy	104	104
Social responsibility	104	89
Emotional self-awareness	85	107
Self perception	102	112
Self-Expression	109	102
Interpersonal	109	103

This student's main takeaways were on emotional self-awareness, impulse control, and their positionality within the historical context of the project and the course. This student emphasized the *"solid understanding of some of the feelings felt by Indigenous people as white settlers came to Canada*". The experiential learning activities made a deep impact on this student, but led to feelings of sadness and pain. This student noted the connection between being aware of emotional intelligence and personal growth, stating: *"Ignorance is bliss in many cases however, I have found with respect to emotional intelligence, this is not the case. If you are unaware of your behaviour, then it is impossible to correct or adjust your thought process to promote personal growth and find peace of from mind."* This student also noted that the categories for which they developed SMART goals (Specific, measurable, achievable, relevant, time-bound) significantly improved. This student also commented on how easy it is to skew the results of the assessment with external factors such as time-of-day, weather, and mood. They noted that their stress management decreased throughout the semester, possible due to the *"external factors clouding [their] judgement at the time of the assessment*".

In addition, the student had a hard time connecting with the project client, commenting: *"I agreed with Joe but didn't know what to say, I felt I was apart of the problem based on my skin colour and upbringing, a feeling I experienced several times during the drip to Tofino.*" These experiences of guilt and discomfort and awareness of their background may have led to hesitancy in social situations, a decrease in self-expression as they become more hesitant to voice opinions, and a challenge to their self-perception (self regard in particular). This may also have led to a withdrawal within interpersonal relationships amongst team members.

Despite the overall decrease in emotional intelligence, the qualitative writings of this student show personal growth in emotional intelligence across many categories and sub-categories. The student concludes that they believe that working on emotional intelligence will help them as an engineer by *"broadening social and intellectual knowledge".* They note that emotional intelligence will help them build connections with clients by listening to their needs.

This study contributes a framework to measure statistically significant changes in the parameters of emotional intelligence, and describes the interventions used to do so. By presenting empirical evidence on how specific activities (such as self-reflective writing, field trips, participatory learning, service learning) may impact EI sub-categories, this study offers novel insights on how engineering courses can be structured to promote the development of social competencies (using emotional intelligence as measurable analog).

3.7 Chapter Summary

Many of the era-defining challenges that engineers face demand an understanding not only of technical competencies, but also of human behaviour, cultural dynamics, and situational context—elements frequently overlooked in engineering curricula. These challenges are categorized as "wicked problems". Wicked problems demand a different approach than traditional engineering challenges. Understanding

and designing for wicked problems requires engineers to be empathetic and emotionally intelligent practitioners. When addressing wicked challenges, engineers must possess a profound comprehension of technical and non-technical factors that will enable them to contextualize solutions within the broader socio-cultural context. The absence of this comprehension within complex, interconnected systems can lead to unforeseen negative consequences.

This chapter explored the results of an intervention intended to test the working hypothesis that integration of design thinking and systems thinking methodologies in a participatory learning environment will increase emotional intelligence. Improving emotional intelligence and introducing engineers to the frameworks of design thinking and systems thinking will help them to address wicked challenges.

The intervention was a course entitled “Infrastructure Design with Indigenous Communities”. This course was carefully designed using best practices from identity formation theory and educational pedagogy. It was implemented at the University of Victoria to increase the social competencies of fourth-year Civil Engineering Students.

Pre-and-post-semester emotional intelligence data collected from a sample of 17 students was analyzed through statistical methods (paired t-tests) and revealed statistically significant increases in overall Emotional intelligence (EI) including the composite category of self-expression, and the sub-categories of empathy, and social responsibility. This study maintained a 95% confidence interval. Data sets were checked for normal distribution using a Q-Q (quantile-quantile) plot.

The findings showed an average overall EI increase of 5.4 points. The t-test for overall EI produced a critical t-value of 3.105 and a p-value of 0.0034, rejecting the null hypothesis that the course would have no impact on EI.

Furthermore, the composite category of self-expression, and the sub-categories of empathy, and social responsibility exhibited statistically significant positive changes post-intervention.

The post-intervention aggregate data on overall EI showed consistent increases in all five composite categories of emotional intelligence. However, only empathy, social responsibility, self-awareness and their composite categories of self-perception, self-expression, and interpersonal were directly targeted by the intervention.

Qualitative data from students' self-reflective writings were gathered and analyzed to triangulate findings of the quantitative assessment and provide additional evidence to attribute the noted changes in emotional intelligence to the intervention.

Some decreases in aspects of emotional intelligence were noted in students over the course of the semester. The reason for this was studied in depth through the students' qualitative writings. It was found in cases of decreases in categories and sub-categories of emotional intelligence, their reflections demonstrated a deeper emotional and self-awareness, empathy, and appreciation for how emotional intelligence will benefit these students in their engineering career. The students noted that the decreases were due to over-confidence during the initial EQi2.0 inventory, confrontation of personal biases affecting their personal regard, and challenges to traditional modes of learning.

Despite the acknowledged limitations of this study and potential biasing factors, this study shows that design thinking and systems thinking frameworks carefully integrated into the engineering curriculum while supporting students' identity formation have promise in elevating emotional intelligence, including empathy, in engineering students. This may produce engineers better equipped to tackle challenging wicked problems.

This chapter contributes to the growing body of research on social competencies in engineering education and practices. It provides a framework for assessing emotional intelligence development. In

addition, it highlights the potential for carefully structured, empathy-focused interventions to produce measurable improvements in the social competence. These skills are essential when addressing wicked challenges, working in interdisciplinary teams, or working across cultures such as with Indigenous communities.

Future research should include the establishment of a control group and a thorough examination of the reliability of trait emotional intelligence testing methods. In addition, additional methods that focus on the other sub-categories and composites of EI should be more deliberately included in order to justify comments on changes to total EI.

This study contributes a framework to measure statistically significant changes in EI parameters, and the describes the interventions used to do so. By presenting empirical evidence backed by qualitative insights on how specific activities (such as self-reflective writing, field trips, participatory learning, service learning) impact EI sub-categories, this chapter offers novel insights on how engineering courses can be structured to promote the development of social competencies.

Chapter 4: Future Work

This course presents promising results regarding the potential of the intervention to increase parameters of students' emotional intelligence. However, there are limitations and confounding factors that could be addressed in future work to increase the rigour, reliability, and validity of the results. These confounding factors and limitations include:

1) **Attribution of results to the intervention:** A limitation of this study is that it cannot be definitively stated that it was the intervention that resulted in the increase in emotional intelligence and the other composite and sub-categories. However, the results in this dissertation are promising and this study maintained a 95% confidence interval and provided validation for attribution from qualitative sources. Still, the results may be explained by students with a disposition towards empathy and emotional intelligence self-selecting into this course based on their interest in the subject matter. The students in this course may have been predisposed to greater levels of self-awareness, empathy, and social responsibility.
2) **Sample Representation:** The small sample size limits the generalizability of the findings. If this course were to become a mandatory elective with a larger sample size and better representation of the engineering student population, the results would be more credible. As mentioned above, the self-selection bias involved with an elective course would be mitigated if the course was mandatory and the sample size was larger. A more diverse sample would improve sample representation and saturation. This may yield results more in-line with those observed by previous researchers. For this study, the elective course was the context that was provided by the Department of Civil Engineering to undertake this work.
3) **Lack of a Control Group:** If this study were to be conducted again within the same context, a control group of students (in the same year as the test group) should be created and analyzed. This control

group would take pre and post-semester emotional intelligence inventories having not participated in the intervention. Ideally, this group would be from a non-elective design course as it would be a better representative sample of the student body. If the students in the control group exhibited a statistically insignificant change in Emotional Intelligence, it would further build the case that the intervention caused the noted change. A control group was sought for this study in a non-elective 4th-year design course, however, there was not enough interest from the students in spending the time to take the emotional intelligence inventory twice throughout the semester. This may indicate that they have little interest in the subject matter to begin with (supporting the self-selection theory) or that they were feeling pressed for time and did not want to add another task to their already busy semesters.

4) **Uncertainty in the Pragmatic Benefits of EI in Engineering:** While the results show statistically significant increases in EI, it is not explored what tangible benefit this had to the outcomes of the designs. Although, the qualitative data showed that many students stated that greater emotional intelligence would allow them to understand interconnections and listen to the needs of client groups, thereby producing better project outcomes. This is also the main argument of this dissertation: engineers must have the tools and mindsets to understand how engineering projects interact with complex systems to produce meaningful results. There may be an ideal EI profile for high-performing designers, which would be interesting to explore. Future research could explore these dimensions by comparing the outcomes of cohorts with and without EI training. The same approach could be taken for the design and systems thinking frameworks. Future work could contrast the project outcomes of cohorts that received design thinking and systems thinking training and those who did not. This would provide clarity if EQ training itself helps produce better results, or if EQ needs a framework such as Design Thinking and Systems Thinking to work through to achieve improved project results.

Chapter 5: Importance of Empathy and Cultural Collaboration in Building (and Rebuilding) Thriving Communities

5.1 Background

This chapter demonstrates the practical application of the interventions noted in this dissertation in addressing the social competence gap in engineering within a real-world industry context. It is included to provide a high-level case study outlining the application of the methodologies discussed throughout the dissertation. It is not provided to present a detailed description of the methodologies used or to provide a detailed analysis and synthesis of the data collected.

The project discussed in this chapter evolved concurrently with the work discussed in the previous chapters. As such, the experiences from the project presented in this chapter provided much of the contextual background that helped to shape in intervention noted in the previous chapters.

Engineers working on infrastructure challenges in cross-cultural settings must have both technical expertise, but also the ability to engage with complex "wicked" problems. This requires the ability to navigate and appreciate cultural differences, appreciate diverse world-views, and co-create solutions through a holistic lens. While the approach presented in this chapter is not without its limitations, and the authors and collaborators view it as a meaningful step toward cross-cultural collaboration in housing with Indigenous communities.

This chapter is included to provide some additional contextual grounding of the dissertation. It delves deeper into the motivations behind the development of the empathetic engineering design framework implemented in the "Infrastructure Development with Indigenous Communities" course. In 2019, while investigating the integration of design and systems thinking in engineering, the authors developed a

relationship with an Indigenous-led organization called the IISAAK OLAM Foundation. The IISAAK OLAM Foundation builds capacity and mobilizes knowledge for the creation of Indigenous Protected and Conserved Areas (IPCAs). IPCAs are lands and waters where Indigenous governments have the primary role in protecting and conserving ecosystems through Indigenous laws, governance, and knowledge systems. Infrastructure and housing are important elements of IPCAs as the links between infrastructure, culture, and environment are profound. This is highlighted in the story at the beginning of this dissertation. They cannot be addressed in isolation from one another.

In partnership with the IISAAK OLAM Foundation, T'Sou-ke First Nation, SHIFT Collaborative, RJC Engineers, the municipality of Sooke, and several other stakeholders, the authors developed a multi-stakeholder working group to explore housing through the lens of IPCAs. What ensued was a three-year journey funded by the National Housing Strategy of the Canadian Mortgage and Housing Corporation (CMHC) called the "T'Sou-ke Housing Solutions Lab" (THSL). The aim of the THSL was to use innovation frameworks such as design thinking and systems thinking to uncover the root causes of housing challenges facing T'Sou-ke First Nation and to find scalable solutions that could be used to address similar challenges facing other Indigenous Nations in Canada. The work undertaken in this chapter could not have succeeded without the support of the organizations mentioned above, as well as others that contributed to the THSL. These organizations were part of the collaborative team that developed research plans, gathered, analyzed and synthesized data, generated solutions, and implemented prototypes. The author of this dissertation was involved in proposal preparation to CMHC, data gathering, data analysis and synthesis, and prototype development, and prototype implementation.

The intervention created to address the social competence gap in engineering described in Chapter 3 co-evolved with insights gained during the T'Sou-ke Housing Solutions Lab. Through this project, the deep interconnections between infrastructure, culture, and environment became evident. It was clear that past engineering and infrastructure projects have contributed to the state of poverty and cultural

erosion seen in so many Indigenous communities across Canada. Equally apparent was the pivotal role that engineers can play in advancing reconciliation in Canada.

As described in other sections of this dissertation, the social competence gap in engineering education has been identified as a significant barrier to engineers' ability to address wicked problems. Housing poverty and infrastructure challenges in Indigenous communities are prime examples of wicked problems. These issues are characterized by their deep-rooted historical, political, and cultural contexts as well as their systemic complexity.

5.2 Introduction

Canada is in a housing Crisis. It is a challenge relevant to many Canadians across the country, but is of particular significance to Indigenous Nations where decades of destructive government housing and land policy have aided in the creation of widespread housing poverty (Wilson & Underwood, 2024).

In 2015 the Standing Senate Committee on Aboriginal Peoples highlighted a worsening housing crisis on reserves across Canada (The Standing Senate Committee on Aboriginal Peoples, 2015). The committee's report highlights that "the existing stock of housing in many communities is in deplorable condition (The Standing Senate Committee on Aboriginal Peoples, 2015)

Housing conditions on reserve have seen limited long-term improvement. Indigenous peoples are still twice as likely to live in a crowded home compared to the non-Indigenous population (Statistics Canada, 2021). Indigenous Peoples are three times as likely as the non-Indigenous population to live in a home in need of major repairs (Statistics Canada, 2021).

Adding to these critical housing challenges, Indigenous communities are also disproportionately impacted by climate related disasters, leading to further damage to the homes, loss of property, and mental and emotional stress.

This chapter describes the methodology of the THSL, the innovative solutions concepts that emerged during this project, and how these concepts have been scaled into engineering education and practice. It also presents a case study demonstrating the application of the empathetic engineering framework presented in Chapter 3 within the context of housing projects in Indigenous communities.

5.3 Methodology

This project employed an innovation framework known as a “Solutions Lab” or “Social Innovation Lab”. It is a process that uses design thinking and systems thinking (described in Chapter 2) to help a design team to uncover, co-develop, and test possible solutions or approaches that can transform the conditions that are giving rise to the problem at hand. As noted in Chapter 2, this is an iterative process and the phases of the process overlap. A solutions lab incorporates the following interconnected ’phases’:

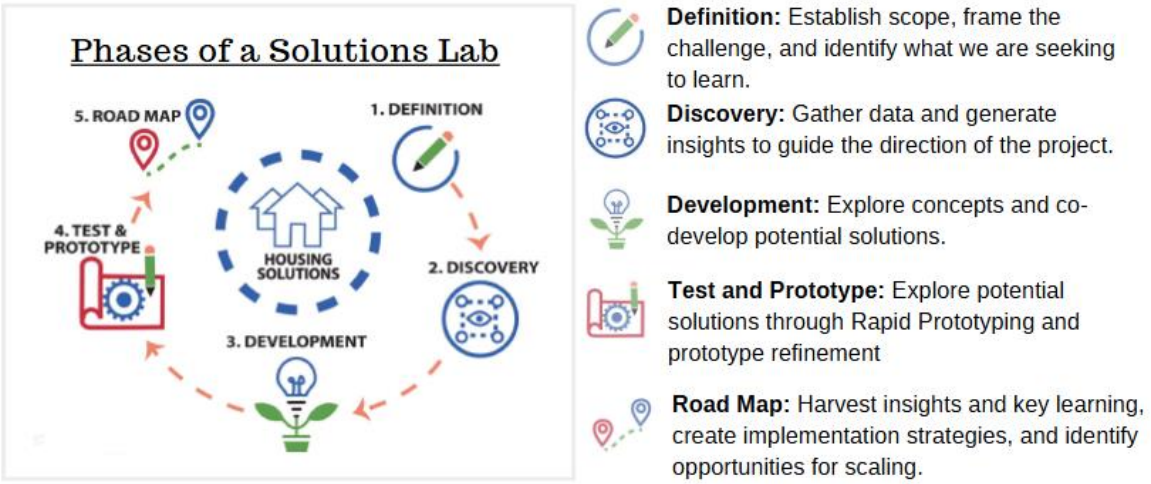


Figure 29 - Phases of a Solutions Lab (SHIFT Collaborative, 2019)

During the “definition” phase, The THSL created an initial frame for the challenge, identified key objectives, established the core lab partners, and defined the project objectives.

Moving to “discovery”, the lab team began to explore the historical context and lived experiences of the challenge by engage with the community and develop insights from community input and contextual research. These insights guided the direction of the project, reframing the challenge as needed.

In the “development” phase, solutions were co-developed with input from community members. Solution themes emerged, and potential prototype areas were determined through input from the community and lab team.

In the “test and prototype” phase, the potential solutions were explored through rapid prototypes and further community engagement and concept refinement.

The final stage was the development of a “roadmap”, harvesting key insights and learning to identify opportunities for scaling.

The THSL approached all lab activities using the methodologies of ethical space, design thinking, and systems thinking:

1. Ethical Space is the interface between two different knowledge systems. It goes back to the historical Peace and Friendship Treaties and the notion of cross-cultural literacy.
2. Design thinking is an iterative process in which we seek to understand the user, challenge assumptions, and redefine problems in an attempt to identify alternative strategies and solutions that might not be instantly apparent with our initial level of understanding.
3. Systems thinking is a high-level approach that identifies the interconnections within the context of an issue and highlights areas where innovations are needed.

This chapter will highlight key activities and insights from this process. The full publicly available final report can be found on the CMHC Knowledge Centre.

5.4 Understanding Historical Context

Having a grounding in historical context is paramount in understanding the challenge, building empathy, and 'framing' the challenge. To understand the conditions that exist on many reserves across the country today, it is important to understand the history of the misguided, damaging, and often overtly racist Indigenous housing policy that created it. To understand the historical context, the design team reviewed publications on historical Indigenous housing policy. In addition, we used qualitative inquiry to gather the perspectives and input of the people that live with these challenges day-to-day.

In ignorance of historical context, those in mainstream society are left to create their own "truths" to reconcile the disparity they observe between the prosperous Canada of their experience and the deplorable state of housing and poverty prevalent in many reserves across Canada. Using the prevalence of condition as evidence to support misguided conclusions, a parallelism is created in the observer's mind between the "poor conditions of on-reserve housing and the personal characteristics of its occupants" (Olsen, 2016). The conclusions drawn, consciously or unconsciously, in the absence of historical context perpetuate bias and prejudice to this day. When the reasons for on-reserve poverty are inappropriately attributed to flaws in the characters of the people suffering it, it at best holds Indigenous communities and peoples as incompetent, in need of further intervention from "competent" actors to lift them out of poverty. At worst, it prescribes poverty as a deserved outcome of personal and cultural flaws.

A disclaimer to the reader: this section may be difficult to read. The authors will occasionally use the term "Indian". This is only done in reference to Government Policy where "Indian" is still the legal term relating to Indigenous peoples under the Indian Act, which is still in effect to this day.

There is a notable lack of academic literature on this subject that would help illuminate this dark corner of Canadian history. As such, the author will draw on publicly available government reviews of

Indigenous Housing policy, census data, and the work of Dr. Sylvia Olsen, who conducted an in-depth review of the Indigenous Housing Policy in her 2016 dissertation “Making Poverty”.

5.4.1 Housing as a Leverage Point for Assimilation

Indigenous housing policy has a long and complex history. It has been shaped by the impacts of colonization, racial discrimination, ad-hoc government policy, and the ongoing struggle of Indigenous peoples to assert their self-determination. The purpose of this section will be to “shine a light” into the lesser known corners of Indigenous housing policy to illuminate the tangled webs of challenges that are connected to the topic of housing in Indigenous Nations.

Prior to European colonization, Indigenous Nations in Canada had their own systems for housing. They were closely tied with cultural and spiritual beliefs, practices, geographic locations. These systems were disrupted by European colonization, which brought Euro-centric forms of housing and land use practices, as well as policies and legislation that sought to assimilate Indigenous people into mainstream Canadian society (Perry, 2003).

Almost immediately after the first settlers arrived in Canada, housing became a “significant site of conflict in the colonial encounter” (Perry, 2003). Indigenous housing was seen as the antithesis to civilized European society. Efforts to reform Indigenous housing to a more “civilized” European way of existence started in the mid 1800’s, a task primarily driven by missionary efforts (Perry, 2003). To the many of the missionaries, Indigenous housing was a physical representation of, and responsible for, what they saw as the ‘deeply problematic character of Indigenous culture’ (Perry, 2003). Housing was seen as a leverage point for assimilation. This is illustrated by the words of Thomas Crosby, a Methodist Missionary who spent a significant amount of time on the west coast of Canada.

“...There is no better teaching than the object lesson of a good and well-ordered Christian home. If he is walking "in His steps," the teacher will naturally illustrate by the fields, the sower, the harvest, the birds,

the fish and by everything around us, and should be able and willing to show how to build a nice little home, from the foundation to the last shingle on the roof. Indeed, this is the only way to win the savage from his lazy habits, sin and misery. So soon as the Missionary gets the language of the people —and every Missionary should do so—he should make an effort to get them out of the wretched squalor and dirt of their old lodges and sweat houses into better homes." (Crosby, 1914).

Support for housing reform grew after British Columbia officially joined the Canadian Federation in 1871 (Perry, 2003). Following the passage of the Indian Act in 1876, the reform became more contentious as the Canadian government placed Indigenous peoples under the control of "Indian Agents," who were authorized to oversee virtually every aspect of their daily lives (Perry, 2003).

John A. Macdonald clearly described the government's view of Indigenous people and the goal of government legislation in 1887 when he stated:

"The great aim of our legislation has been to do away with the tribal system and assimilate the Indian people in all respects with the other inhabitants of the Dominion as speedily as they are fit to change." (Giokos, 1995)

When the Indian Act was established in 1876 it was not conceivable to government officials that the Indigenous communities relegated to small reserves would turn into permanent settlements (Olsen, 2016). It was assumed that Indigenous people would die off or be absorbed into mainstream society. Again as evident from the sentiment by the author of the forward to Thomas Crosby's book:

"...There is but one native race in Canada, now rapidly passing away, the North American Indian...In the West he is gradually yet sullenly retreating before the progress of the White Man and his civilization, and the day seems not far distant when he must be absorbed by that advancing progressive life or be pushed into the Western Sea…" (Crosby, 1914).

5.4.2 The Indian Act

The Indian Act of 1876 has played (and continues to play) a significant role in the dispossession of Indigenous peoples from their traditional territories in Canada and the creation of the housing crisis seen on many reserves to this day. A review of the present day impacts of the Indian Act could be the topic of a dissertation in-and-of itself. Therefore, this section will summarize some key sections of the Indian Act legislation that relate to housing and the Indigenous housing crisis.

Under Indian Act Section 1, the government was granted significant control over Indigenous life in Canada (Olsen, 2016). Indigenous Nations were organized into "bands" (sometimes breaking large Nations apart into separate bands) and were assigned to specific tracts of land that were “legally owned” by the Crown but set aside for the exclusive use of the Indian Band. This legal arrangement meant that, according to British law, Indian bands only had an occupational relationship to the land and did not hold any inherent cultural rights or ownership over it, despite their deep cultural and spiritual connection to the land.

In an effort to re-establish the severed connection with the land (and consequently, languages and cultures) Indigenous peoples started to organize politically to pursue land claims in the 1920’s. The federal government promptly amended the Indian Act and added Section 141. Section 141 made it illegal for Indigenous people to hire lawyers or seek legal counsel, effectively preventing them from using the legal system to assert their rights (University of British Columbia, 2009). These restrictions on legal representation were later expanded to prohibit virtually any kind of gathering, resulting in imprisonment for those who violated these rules (University of British Columbia, 2009).

Disconnections from traditional territory has led to social and cultural disruption. It is a well-known fact that Indigenous peoples’ cultures and languages are intimately connected to their traditional territories. Continued connections to traditional territories is essential for the maintenance of cultures and

traditions. For Indigenous peoples, the land is more than just a geographic location, it is the origin of spiritual connection, cultural identity, and language.

Sections 61 and 62 of the Indian Act gave the Crown, via government officials known as “Indian Agents”, authority over financial transactions related to reserves. This control extended to all reserve revenues, including those earned through the sale and use of land and natural resources. Indian Agents were also given control over the daily management of Indigenous peoples and communities, including in the distribution and construction of housing. This undermined autonomy and self-determination (Olsen, 2016).

From the 1890s to the late 1940s, the federal government sold off large parcels of reserve lands in order to replenish band capital accounts. Part of these funds were then used to fund on-reserve housing programs (Olsen, 2016). This further disposed Indigenous peoples of their traditional territories. The band accounts had been depleted due to the purchase of small packages of building materials that were provided to those deemed “most in need” in order to self-build a home for their family. The policy did not provide the provision of skilled labour to complete the work and the materials that were provided were only enough to build a rudimentary, uninsulated shelter (Olsen, 2016).

The Indian Act’s policies related to housing resulted in widespread housing issues for Indigenous peoples living on reserves. Many families were forced to live in overcrowded, substandard homes that lacked basic insulation and amenities (like water, electricity, or plumbing).

The overcrowded and poorly constructed homes on reserves, which were a result of the negative policies contained in the Indian Act, contributed to high rates of illness, particularly tuberculosis.

The substandard condition of housing and the prevalence of illnesses due to the woefully inadequate housing policies were used to justify the forced removal of Indigenous children from their families as part of the residential school system (Olsen, 2016).

Residential schools were the sites of widespread abuse and atrocities. The residential school system has had a profound impact on Indigenous Nations across Canada. It disrupted transmission of cultural practices. It destroyed languages. It destroyed families. It destroyed lives. To this day, intergenerational trauma from residential schools is perpetuating negative socio-economic outcomes.

Section 89 was intended to protect Indigenous land from being transferred to non-indigenous people. Section 89(1) of the Act reads as follows:

"Subject to this Act, the real and personal property of an Indian or a band situated on a reserve is not subject to charge, pledge, mortgage, attachment, levy, seizure, distress or execution in favour or at the instance of any person other than an Indian or a band." (Government of Canada, 2021)

While this may seem like a section of policy in-favour of Indigenous peoples, this section had the consequence of making it impossible for members of an Indian band to use on-reserve assets as collateral for any bank loans, and denied residents access to the vehicles available to mainstream society for home building (Government of Canada, 2021) (Olsen, 2016). As a result, Indigenous people faced discrimination when trying to access housing off reserves. Many mainstream housing markets were closed to Indigenous people (Olsen, 2016).

5.4.3 Ministerial Loan Guarantees and Section 95 Housing

Ministerial Loan Guarantees (MLGS) were introduced by the federal government in 1966 as a way to provide a path for Indigenous peoples to borrow money to build homes (Government of Canada, 2021).

By providing an MLG the Minister guaranteed that the “Crown will repay the loss incurred by a lender if a First Nation defaults on loans with the lender” (Government of Canada, 2021).

In the event of a loan default or non-payment, the ministry had the authority to evict tenants and sell or rent the home to other band members. However the burden of enforcing repayments and evictions fell

to band councils and administrations (Olsen, 2016). This put Band Councils and Band Administrations in extremely uncomfortable and burdensome situations. If the loan was not re-payed, funding would be recovered from federally supplied program funding – funding for this such as administration, family and health services, education, cultural and language revitalization (Olsen, 2016). In addition, if the loans were not re-payed, the responsibility to evict band members also fell on the Band Administration, however they also had an obligation to find them other accommodations. This usually meant the non-payers would move into another relative's homes, causing further overcrowding (Olsen, 2016)

A 2010 evaluation of current MLGs implemented since 1996 stated that "there is some interview evidence to suggest that building more housing units using MLGs, has contributed negatively through the creation of cash flow problems as a result of higher debt loads in some First Nations communities" (Indian and Northern Affairs Canada, 2010). Later in that same evaluation they state: "without a clear understanding of the implications of increased debt load and managing cash flow, communities often struggle to maintain financial health" (Indian and Northern Affairs Canada, 2010) and even acknowledge that "many communities use funding earmarked for other areas to pay back their mortgage loans" (Indian and Northern Affairs Canada, 2010). The review found that a number of First Nations reported financial difficulties due to loan repayment, resulting in third-party intervention, which would lead to either a turnaround in the management of the housing portfolio, or to chronic debt and a cutback in the number of programs and capital expenditures (Indian and Northern Affairs Canada, 2010).

Section 95 Housing was introduced allowing Indigenous Nations t become not-for-profit housing corporations. This allowed bands to access CMHC backed loans for low-to-middle-income housing projects. Similar issues to MLG backed homes placed additional financial burden on band in the event of non-payment – facing the loss of community funding.

5.5 Present Day Impacts

A review of on reserve housing conducted in 2017 stated that “housing programming led by INAC as far back as the 1960s, and culminating in the current approach that has been implemented since 1996 have proven ineffective”. Housing conditions have seen limited long-term improvement (The Standing Senate Committee on Aboriginal Peoples, 2015).

Indigenous peoples are still twice as likely to live in a crowded home compared to the non-Indigenous population (Statistics Canada, 2021).

Indigenous Peoples are three times as likely as the non-Indigenous population to live in a home in need of major repairs (Statistics Canada, 2021).

On reserve, 35.7% of First Nations people with Registered or Treaty Indian status under the Indian Act still lives in a crowded home and 37.4% lived in a home in need of major repairs (Statistics Canada, 2021).

The socio-economic impacts of living in an inadequate building are well documented in the literature. Poor housing conditions lead to a multitude of health concerns including tuberculosis, meningitis, measles, respiratory disease, hepatitis, mental health issues, and intestinal, skin, and ear infections (Robson, 2008).

Poor housing is a mechanism of social stratification. It affects the earning potential of adults and hinders children’s positive development resulting in the intergenerational transmission of social inequality (Solari & Mare, 2010). For children living in poor housing conditions the negative effects of can persist throughout their life, affecting their future socioeconomic status and adult wellbeing (Solari & Mare, 2010). A study published in the Journal of Preventative Medicine showed evidence extended periods

living in inadequate housing in the past was still correlated with poorer mental health in the present (Pevalin, Reeves, Baker, & Rebecca, 2017).

Mental health disorders operate in a self-perpetuating cycle that can impair immune, cardiovascular, and hormonal functions. These in turn lead to a further deterioration of physical health and may lead to a reduction in disposable income through disability, unemployment, and increased medical costs (Liddell & Guiney, 2015)

Adding to these critical housing challenges, Indigenous communities are also disproportionately impacted by climate related disasters, leading to further damage to the homes, loss of property, and mental and emotional stress.

5.6 Reframing the Challenge

The challenge was reframed based on community engagement (focus groups) and contextual research. For both Indigenous and non-Indigenous participants, it was found that healthy homes are connected to healthy communities, and healthy communities are connected to healthy ecosystems. With knowledge of the historical context and input from the community, the framing of the project with the T'Sou-ke Housing Solutions Lab shifted to:

" 'home' is not limited to the structure of the house, but encompasses the broader environment—the sources of food and water that nurture our families; the cultural practices, traditions and languages that develop our sense of who we are; the spaces in which we raise our children, and the sacred places where our ancestors lay to rest. Personal, community, and environmental health and well-being are inextricably linked and cannot thrive in isolation."

Based on this shared understanding of "home" we developed the following questions:

How might we…

1) ". . . support community health, wellbeing, and connection to ecosystems within T'Sou-ke Traditional Territory through the creation of housing strategies that embrace Indigenous worldviews of "home"?"
2) ". . . develop housing strategies that foster and honour peace and friendship treaty responsibilities between Indigenous and non-Indigenous residents living within the traditional territory of T'Sou-ke Nation?"

What was initially framed as a focus on on-reserve housing models within T'Sou-ke First Nation, became a way to create a shared vision and understanding between municipal and Indigenous governments for 'home' within the traditional territory of T'Sou-ke First Nation.

After reframing the project, the priorities of the THSL also shifted. We now endeavored to:

1. Increase dialogue between T'Sou-ke Nation and key regional stakeholders to influence local development in a way that honours both Indigenous and western worldviews.
2. Articulate a vision and test solutions for community housing innovations which can better support Indigenous cultural, social, economic, and ecological sustainability and health.

The project pivoted from initially anticipated results – which was to create floor-plans and design drawings for culturally inspired housing – into a holistic concept of "home" including reconnection to traditional territory and culture, and fostering personal, community, and environmental health and well-being.

5.7 Results - Developing Solutions Concepts

After this in-depth review of historical housing policy and witnessing the real-world examples of how historical policy and present day impacts converge, it was clear that simply focusing on culturally

appropriate home designs would not be an adequate solution to the housing challenges faced by Indigenous Nations (although it is one important aspect of the challenge).

Housing poverty is an all-to-prevalent downstream effect of a long and complex history. The underpinnings of relations between Indigenous Nations and Government are still based on the Indian Act. As long as that legislation is in-place, the mental models present at its conception will remain.

Although it is important to address the "seen" aspects of a problem (i.e. resilient and appropriate housing infrastructure is vitally needed) to create long-lasting change, solutions must acknowledge the connections to other challenges that remain less visible.

This is identified by Arthur Manual, and quoted by Dr. Sylvia Olsen at the end of her dissertation:

"To be absolutely clear, we are not talking about stop-gap programs and services that are created under federal and provincial legislation. And we are not talking about action that is purely for disrupting the establishment without any real plan of what kind of future we want to create. We are talking about fundamental change that recognizes our title to our territories and our right to self-determination. This is where we [must be] headed." (Olsen, 2016)

From engagement with the community, solutions concepts were grouped into four key impact areas with potential solutions for exploration:

1) Naut'Sa'Mawt (Working Together as One) strategies for co-leading and collaboration on housing and land-use in T'Sou-ke Traditional Territory.
    a. Creating a joint Sooke/T'Sou-ke Housing Advisory Council to increase representation of T'Sou-ke voices in planning for housing and land-use.
2) Indigenous Protected and Conserved Areas
    a. Establishing a T'Sou-ke IPCA to reconnect members to traditional territory

b. Establishing an IPCA Approach to Housing (IPCA Ecovillage concept).

3) Cross Cultural Education

   a. Developing a respect for Indigenous relationships to the region through place-based education.

   b. Developing a university level course to support infrastructure design for Indigenous Communities from a holistic lens.

   c. Developing a prototype team in engineering industry to employ this holistic approach to engineering design in real-world challenges.

4) Culturally appropriate housing for diverse and evolving needs

   a. Creating culturally appropriate homes and home designs

   b. Developing a housing Needs Assessments for the community

   c. Creating a tool to help members navigate on-reserve housing systems (community compass)

While the solutions concepts are presented for the interest of the reader, this dissertation focused on solution concepts 3b and 3c. The development of this prototype solution is described in depth in chapters 1 – 4 of this dissertation. The other prototype solutions were also explored, but are outside the scope of this dissertation. The full publicly available final report can be found on the CMHC Knowledge Centre.

Key insights, methods, and learnings from the T'Sou-ke Housing Solutions Lab process were integrated into the fourth-year engineering course discussed at length in Chapter 3. This was done as part of the road-map to mobilize the knowledge gained from the project, and to attempt to integrate this knowledge into engineering industry.

As outlined in Chapter 3, the course framework was designed to incorporate design thinking and systems thinking , allowing students to recognize and respect the complex contextual landscape in which infrastructure is situated. This better positions future engineers to tackle complex, "wicked" challenges with a culturally informed and innovative approach. This was seen as an important step in the road-map to scale lessons learned from the T'Sou-ke Housing Solutions Lab.

5.7.1 Scaling the Framework in Engineering Practice

In addition, the THSL team determined that another avenue for knowledge mobilization and scaling was to integrate the framework for a holistic engineering design approach directly into engineering practice. The IISAAK OLAM Foundation (IOF) and RJC Engineers established a unique partnership to form a team that combines cultural awareness and guidance (provided by IOF) with technical engineering expertise (offered by RJC). The team was named the IISAAK Engineering Team (IET). This collaboration enables the team to address infrastructure and housing challenges in Indigenous communities with the empathetic and interconnected approach outlined in this dissertation.

As highlighted throughout this dissertation, it is vital for engineers working with Indigenous communities to be aware and respectful of the intimate system of connections between infrastructure, culture, historical context, and the environment. They must have an understanding of "wicked problems" and the interconnected and empathetic approach to design that they demand to produce meaningful solutions.

This approach to infrastructure development seeks to directly address Call to Action 92 of the Truth and Reconciliation Commission's 94 Calls to Action, promoting reconciliation through ethical, culturally sensitive practices.

5.7.2 Housing as a Leverage Point for Reconciliation

In 2015, the Truth and Reconciliation Commission (TRC) of Canada issued 94 calls to Action. These actions were aimed at redressing the legacy of residential schools and advancing the process of reconciliation in Canada.

Call-to-action 92 is a specific call for the corporate sector. It calls for the corporate sector to "adopt the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) as a reconciliation framework and to apply its principles, norms, and standards to corporate policy and core operational activities involving Indigenous peoples and their lands and resources" (Truth and Reconciliation Commission of Canada, 2015)

In addition, it calls for the corporate sector to: (1) take time to build meaningful relationships, (2) ensure equitable access to jobs, training, and educational opportunities for Indigenous peoples, and (3) educate management and staff on the history of Aboriginal peoples, including the history and legacy of residential schools and UNDRIP, amongst other important calls.

UNDRIP was adopted in Canada as a reconciliation framework on June 21, 2021. In short, UNDRIP establishes "a universal framework of minimum standards for the survival, dignity, and well-being of the Indigenous Peoples of the world and it elaborates on existing human rights standards and fundamental freedoms as they apply to the specific situation of Indigenous Peoples" (United Nations, 2024)

There are three articles in UNDRIP that have particular importance to these housing projects. They are UNDRIP Articles 21, 23, and 31.

Article 21:

1) "Indigenous peoples have the right, without discrimination, to the improvement of their economic and social conditions, including, inter alia, in the areas of education, employment,

vocational training and retraining, housing, sanitation, health and social security“ (United Nations, 2007)

2) “States shall take effective measures and, where appropriate, special measures to ensure continuing improvement of their economic and social conditions. Particular attention shall be paid to the rights and special needs of indigenous elders, women, youth, children and persons with disabilities” (United Nations, 2007)

Article 23:

1) “Indigenous peoples have the right to determine and develop priorities and strategies for exercising their right to development. In particular, indigenous [sic] peoples have the right to be actively involved in developing and determining health, housing and other economic and social programs affecting them and, as far as possible, to administer such programs through their own institutions” (United Nations, 2007).

Article 31:

1) Indigenous peoples have the right to maintain, control, protect and develop their cultural heritage, traditional knowledge and traditional cultural expressions… (United Nations, 2007).

5.7.3 Empathetic Engineering Design – A Pragmatic Example

In November 2021. An “atmospheric river” brought significant rainfall to regions of British Columbia. In some locations, rivers swelled to between four and seven times their max flows typically seen in autumn rainfall events. It is important to note that in some regions, the 2021 atmospheric river brought almost 50% more rainfall than the worst-case RCP 8.5 climate projections for a 5-day rainfall event in just 2 days. This shows that in reality extreme weather events may significantly out-pace projections. This

rainfall led to significant flooding across BC's Lower Mainland and Vancouver Island, causing significant damage to critical infrastructure and housing.

Similar flooding events are expected to reoccur in the region and be intensified by climate change. The IET is now implementing the design and systems thinking frameworks for engineering developed (in-part) during the T'Sou-ke Housing Solutions Lab in large projects responding to the devastating 2021 atmospheric river.

In 2021 the IET was engaged through RJC Engineers by Nations in British Columbia impacted by the flooding to conduct Building Condition Assessments (BCAs) on 45+ flood damaged structures to determine if they could be lifted above the 200-year Flood Construction Level.

In general accordance with the Structural Condition Assessment of Existing Buildings Professional Practice Guidelines as published by EGBC in relation to Limited Scope Assessments, the purpose of the BCAs were to:

1) Note the general layout and type of construction
2) Survey the condition of the building to identify obvious, relevant, and significant instances where the construction may have been completed incorrectly.
3) Observe obvious signs of structural damage, deterioration, distress, or deformations, including settlement or foundation problems related to flooding events.
4) Observe obvious conditions that may lead to water ingress and deterioration of building systems during high precipitation flooding events.

Employing techniques from design thinking and systems thinking, the IET met with community members in their homes and listened to their experiences with the flood. Much was shared about the traditional territory, the way the area has changed over the years, the impacts of government policy, and the

impacts of logging in the watershed (which many feel have exacerbated the effects of the flooding event regionally).

In addition to the qualitative information gathered from Nation members through the BCA process, an in-depth review of future climate predictions for the area was conducted. This resiliency assessment was conducted to inform future design decisions and development strategies to improve the resiliency of the Nation. This assessment was conducted using the following methodology:

1) Engage with community members, particularly those with a large amount traditional knowledge and lived experience in the area, to gather qualitative, location specific context.
2) Review the Climate Atlas Report specific to the Nations.
3) Conduct desktop studies using the Climate Change Atlas of Canada the CCCS Climate Atlas of Canada considering RCP 8.5 for various Hot Weather, Cold Weather, Temperature and Precipitation projections for 2021-2050 and 2051-2080.
4) Conduct desktop studies using ClimateData.ca, considering RCP 8.5 High Carbon Climate Future with projections for 2080.
5) Review climate projection reports published by neighboring municipalities.

By listening to the home owners, consulting with the Nations, witnessing the condition of the homes, and conducting option analysis and cost-benefit analysis, it was determined that simply lifting the existing structures above the 200-year flood construction level would not be a sufficient long-term solution to housing resilience in the Nations. In some cases, the homes were already posing a risk to occupant health and safety and had suspected remediation items (e.g. mould). The resources needed to properly locate, assess, and remediate issues within the structure would be time consuming, expensive and unpredictable. Due to the nature of remediation the occupants would be relocated for an

unpredictable amount of time which would not only have impacts on project scheduling, but also on mental and physical health.

Exacerbating the remediation issue, the climate resiliency assessment indicated the deterioration of as-constructed housing and community infrastructure in the Nations are likely to accelerate due to more frequent, more intense rainstorms and flooding events. It is anticipated that a milder, more humid climate will increase moisture load in buildings and may lead to optimal conditions for mould to thrive.

In partnership with the Nation leadership, it was determined that replacement of the flood-damaged structures was the most appropriate course of action for the long-term resilience of the Nations. However, new homes would need to be designed to be resilient to future flooding events and built to the 200-year Flood Construction Level (as determined through hydrological models). This would provide a resilient path forward for the Nations to mitigate future flood damage.

5.7.4 Acknowledging Interconnections

As discussed previously, a key lesson of the T'Sou-ke housing solutions lab was to acknowledge and address other interconnected challenges linked to housing. In this way, housing projects can be used as a leverage point to support the achievement of other elements of self-directed community visions. For these projects, other considerations included: cultural revitalization, educational outcomes for children, capacity development, and vocational training. In addition, the social impact of investing into improved housing for Indigenous peoples was explored as a potential means build the economic case for the projects to the government.

Culturally Informed Home Designs

During design, by deeply engaging with the affected families over several in-person design meetings, the IET learned of the cultural and personal significance of "home" for each family. It was identified that the

homes must not only address practical needs but also mirror the unique visions and cultural values of the occupants, paired with the best of modern western building science to enhance the homes' energy efficiency and resiliency.

This engagement with the Nation members led to the co-creation of custom-designed homes that aimed to reflect each family's unique needs. In some cases, the occupants required culturally informed layouts to accommodate cultural practices such as drumming, dancing, and rituals around healing, death, and traditional medicines. This included the inclusion of flex space that could be converted into space for drumming circles, dancing practice, or additional sleeping quarters when cultural protocol prohibits spouses from sharing bedrooms for long periods of time. In addition, artistic styles specific to the Nations were incorporated into the homes in both the architectural design, and on exterior address markers of each home.

In many cases the homes being replaced were built by grandparents or great grandparents and have been passed down through multiple generations. This comes with some challenging emotions for the home owners as memories of grandparents, parents, and children are connected to the physical structures. It was important to acknowledge this connection, and to start each project in a respectful way.

Prior to demolishing the existing structures, some Nation members chose to mark the occasion in ceremony to thank ancestors for their commitment to providing shelter for their families. Some people thanked the structures for the service and protection they have offered.

Once each home was completed, the families are welcomed home in ceremony – marking the occasion with welcoming songs and words from community elders.

These considerations aim to bring an aspect of culture into the projects.

Educational Outcomes

In some instances, the homes were found to be overcrowded. It was not uncommon to see intergenerational families of 12 or more in a home. In some cases, family units of five people (two adults and three children) within the homes were sleeping in a single room of approximately 100-square-feet. Overcrowding has been shown to have impacts on childrens' learning and future socioeconomic potential (Solari & Mare, 2010).

Living in a crowded home is negatively associated with multiple aspects of a child's well-being (Solari & Mare, 2010). In cases where overcrowding was noted, with the blessing of the Nation Leadership, the IET was able to petition government programs to approve additional square footage in the re-built home to reduce overcrowding and provide increased space for children to have their own rooms and study spaces. This may have positive long-term outcomes in the Nation as children experience reduced educational, behavioral, and physical health disparities (Solari & Mare, 2010).

Capacity Development and Economic Opportunities

During the procurement phases, the IET worked with the Nations to identify contractors who reflected the values of the Nations, demonstrated a commitment to reconciliation, or were Indigenous owned. This helped in incorporating Indigenous led organizations and allies into the supply chains.

In support of TRC call to action 92 and UNDRIP 21 and 23, the duration of one of the projects allowed the Nation, IET, and General Contractor to co-develop and implement a significant Nation-directed capacity development initiative where 16-to-18 Indigenous apprentices from the Nation and surrounding Nations entered into an on-site vocational training program for 5-years.

This program, a first-of-its-kind in Canada, was designed to remove barriers to entry and success for Indigenous peoples, bringing the class-room to the job-site. By establishing Indigenous apprenticeship

positions and supporting the delivery of curriculum close to home, the initiative will support individuals through a five-year journey to become re-seal journeyman carpenters. This commitment to skill development not only empowers the community but ensures that the rebuilding efforts are sustainable, contribute to long-term resilience and livelihoods, and embeds capacity within the Nation to support other elements of their Comprehensive Community Plan - such as education, vocational training, and developing Nation-led businesses.

Social Return on Investment

A recent report on the Urban, Rural, and Norther Indigenous Housing Strategy published by the Aboriginal Housing Management Association highlights the profound social and economic benefits of investing and improving housing conditions in Indigenous communities. Their Social Return on Investment (SROI) analysis provides a compelling argument into the economic viability of these types of projects. It may be that the benefits to the local, regional, and national economy far outweigh the initial investment.

The SROI analysis indicated that “for every dollar invested in Indigenous housing every year, there is a Social Return on Investment of, as a conservative estimate, $7.40. This includes an estimated $2.90 in government savings resulting from decreased government service use” (Aboriginal Housing Management Association, 2022). This is due to fewer resources being spent on health care, emergency services, and social welfare due to the improved socio-economic conditions that appropriate housing provides. The SROI analysis found that each year that $42 million is invested in Indigenous housing, over $314 million in social and economic value is produced. This highlights the systemic complexity of housing.

This SROI suggests that investments into improved housing conditions for Indigenous peoples are not merely expenditures. They could be seen as strategic, long-term investments into societal well-being that are both fiscally and morally responsible.

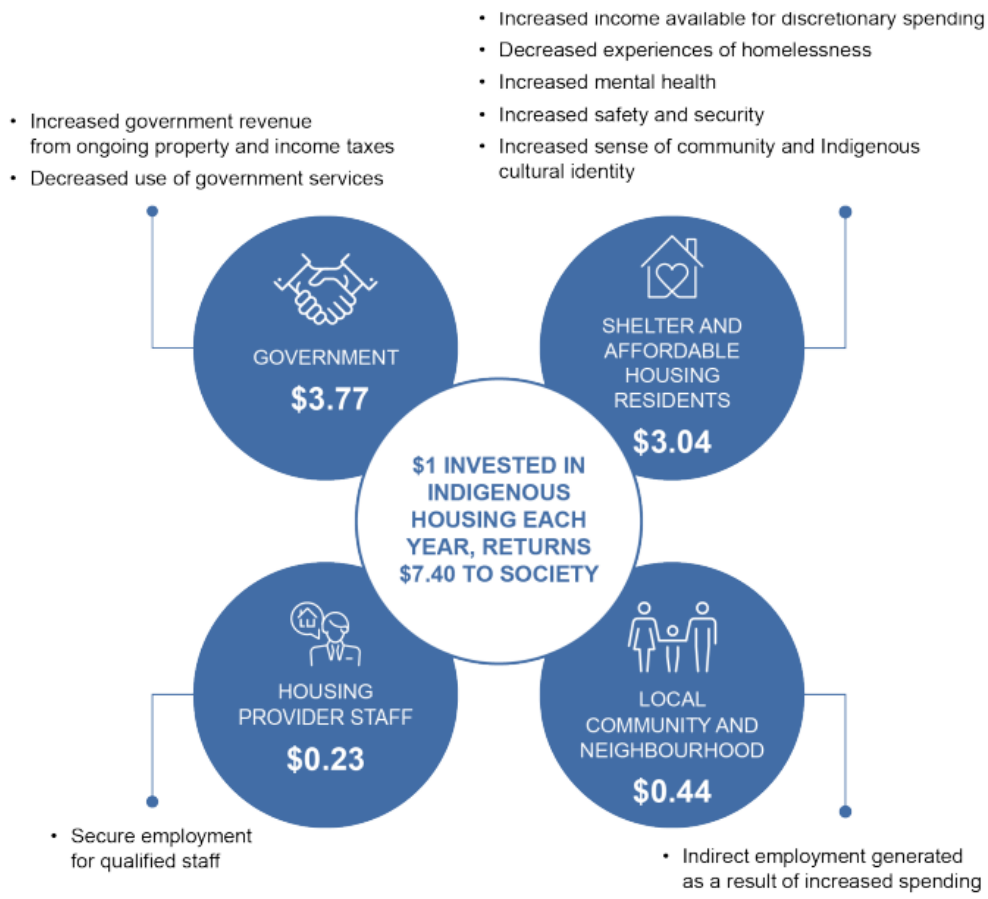


Figure 30 - Social Return on Investment of Indigenous Housing (Aboriginal Housing Management Association, 2022)

"Broken down by stakeholder, 50% goes back to government as revenue and cost savings from reduced service use. The amount that goes back to government is almost four times the value of the original investment. Another 41% of the value is social value of tenants of subsidized housing and individuals and families staying in emergency shelters. Approximately 6% goes to businesses in the local community and neighborhood and 3% goes to staff of AHMA's housing providers. Adequate housing is a tangible and long lasting aspect of reconciliation". (Aboriginal Housing Management Association, 2022)

As an antithesis to the strategic positioning of housing as a means to assimilation taken by the federal government during the establishment of the dominion of Canada, contemporary investment into

improved housing conditions could be used as a leverage point for reconciliation and cultural resurgence. Housing is the nexus of personal and societal well-being. Housing can be used to address root causes of poverty while fostering economic growth.

Table 33 presents a summary of some of the approaches taken during the aforementioned projects, and how these actions answered the call to meaningful acts reconciliation.

Table 33 - Housing as a Means of Reconciliation

Action taken	**Reconciliation framework supported**
Involvement with the THSL	▪ Call to Action 92: education for management and staff.
Undertaking cultural acumen training for engineering management and staff (KAIROS blanket exercise and training with IOF)	▪ Call to Action 92: education for management and staff.
Implementing culturally informed co-design of housing.	▪ UNDRIP Article 21: right to improvement of economic and social conditions. ▪ UNDRIP Article 23: Right to be actively involved in the development of housing. ▪ UNDRIP 31: right to cultural expression.
Building meaningful relationships with leadership and membership	▪ Call to Action 92.
Integration of cultural protocol surrounding demolition/occupancy.	▪ UNDRIP 23: right to self-determined development. ▪ UNDRIP 31: right to cultural expression.
Co-design and implementation of Indigenous trades program	▪ UNDRIP Article 21: right to improvement of economic and social conditions. ▪ UNDRIP Article 23: right to self-determined development.
Petitioning funding agencies to provide additional funding to reduce over-crowding and provide space for children's educational attainment.	▪ UNDRIP Article 21: right to the improvement of social conditions.
Design and construction of resilient, mould-free homes	▪ UNDRIP Article 21: right to improvement of social conditions and health.

5.8 Challenges in Implementing the Framework: A Reflection on Reconciliation in Engineering Practice

In the process of implementing this framework in practice, several challenges and pitfalls were identified. This has helped the IET to improve its services and will lead to a more robust solution concept that can be scaled to other engineering offices across Canada.

1) Respecting Historical Context

As previously noted, understanding and respecting historical context is vital when working with Indigenous Nations. As heard time-and-again through engagement with Indigenous communities and Nation members, there is a longstanding history where construction professionals and engineers have exploited Indigenous Nations for profit. The IET heard many stories from Nation members and leadership of construction professionals compromising on quality and pocketing the savings to maximize their gains. This left Indigenous peoples with poorly constructed infrastructure that deteriorated quickly. The impact of practices such as this have created a justified mistrust in western construction and engineering professionals in many communities.

Professionals who wish to engage with Indigenous Nations today must be aware that they may be stepping into a space where historical injustices in the design and delivery of housing projects are still prevalent. Many Nations are still contending with the impacts of inadequate government policy pertaining to housing and predatory construction professionals seeing a way to make a greater profit. In some cases this context has led to justifiable skepticism. This can make it difficult for professionals to prove their good intentions.

Those seeking to work with Indigenous Nations must be aware that they are often contending with an uphill battle against this historical context—and rightly so. Acknowledging this history is the first step in building a foundation for empathy. Empathy and understanding will make interpersonal challenges easier to navigate.

2) Building Relationships and Trust

The responsibility to build trust rests on the construction professionals and consultants who wish to engage with Indigenous Nations. Earning this trust can be challenging, especially when well-intentioned efforts are met with skepticism or outright hostility. This can be discouraging and demoralizing. However, this is what reconciliation in practice demands—time, humility, and a commitment to genuine engagement. Sometimes it requires a thick-skin.

Trust is earned through consistent, transparent actions – something that construction professionals and consultants must keep in mind while working in this space. This means not only meeting expectations but aiming to exceed them. Construction professionals and consultants must show that commitment to quality, integrity, and the development of a strong relationship is unwavering. Moreover, professionals must be prepared to listen to the concerns and needs of the Nation Leadership and members and adapt their practices accordingly. No construction project ever goes 100% according to plan, so when mistakes happen, professionals must own-up to them and do what they can to make it right.

Just as Walther et al noted of engineering education, engineering practitioners must also focus on the notion of a "whole professional". Find ways to integrate personal values and beliefs with professional goals and actions. Walther et al suggest that engineers must "fundamentally grapple with the contextual and deeply personal question of what it means to be an engineer in the world" (Walther, Miller, & Sochacka, 2017). Building meaningful relationships requires more than just professional engagement; it

requires showing up as a whole person. Not merely as a representative of a professional organization. Show who you are. Make friends. Share laughs, food, and when appropriate, tears.

Engineers and consultants need to be willing to engage on a human level, sharing not only their expertise but also their values, intentions, and respect for the culture and traditions of the Indigenous communities they serve. This might mean participating in cultural ceremonies, understanding the significance of the land and its history, and being open to learning from the community. Be humble.

By bringing their whole selves to the project, professionals and Nation Leaders can begin to create a space where collaboration is based on mutual respect and shared goals. This approach not only enhances the quality of the work but also helps to build lasting, trust-based relationships.

Developing Positive Communication Channels

Respecting communication protocols and ensuring that Nation leadership and members are consistently informed about project details is critical. Indigenous communities often have their own established communication protocols and cultural practices that guide how information is shared and decisions are made. Establish appropriate communication channels with Nation leadership early in the project. Understanding and adhering to these protocols is essential for fostering respectful and effective communication. This may involve more face-to-face meetings, and allowing more time for decision-making processes that involve community consultation or Chief and Council deliberation.

Also note that typical engineering communication methods and language may not always be effective or well-received in these contexts. Engineers and consultants must be mindful that their standard methods of communication, which may be effective in other settings, could be perceived as impersonal or even dismissive and patronizing. As such, professionals need to be adaptable, ready to modify their communication styles and deliverables to meet the needs and expectations of the Nations they are working with.

5.9 Conclusions and Future Work

Housing conditions on-reserve have seen limited long-term improvement. Indigenous peoples are still twice as likely to live in crowded homes, and three times as likely to live in a home in need of major repairs. The research is clear that living in conditions such as this has a significant impact on the health and well-being of the occupants, especially children. These conditions are likely to create reverberating challenges throughout life.

In 2019, the "T'Sou-ke Housing Solutions Lab" used frameworks of innovation (such as design thinking and systems thinking) and cross-cultural collaboration (such as ethical space and two-eyed-seeing) in an attempt to uncover the root causes of housing challenges facing T'Sou-ke First Nation. Moving beyond a narrow focus as "home" as the physical structure of a house to consider the holistic and interconnected aspects of community, culture, environment, and well-being, the Lab team was able to identify promising solutions to the housing crisis that could be scaled to other Indigenous Nations in Canada. The project shifted from merely creating culturally inspired home designs, to proposing solutions that fostered a deeper connection to traditional territory, culture, and community.

Key to the success of the "T'Sou-ke Housing Solutions Lab" was the use of a co-leadership model that brought together Indigenous and non-indigenous peoples to create a shared vision for home within the territory of T'Sou-ke First Nation.

Prototypes that emerged from this project included a fourth-year university course for civil engineers at the University of Victoria aimed at increasing cultural awareness and collaboration when developing infrastructure in partnership with Indigenous Nations. The model for this course is discussed in depth in Chapter 3.

In addition, these lessons were integrated into industry practice through the establishment of the "IISAAK Engineering Team" (IET) an innovative relationship between the IISAAK OLAM Foundation (an Indigenous-led not for profit organization). and RJC Engineers (a for-profit engineering firm).

The IET combines cultural awareness and guidance (provided by IISAAK OLAM) with technical engineering expertise (offered by RJC). This collaboration enables the team to address infrastructure and housing challenges in Indigenous communities with the empathetic and interconnected approach developed during the T'Sou-ke Housing Solutions Lab. This approach to infrastructure development seeks to directly address Call to Action 92 of the Truth and Reconciliation Commission's 94 Calls to Action.

The IET was mobilized on several large housing projects in British Columbia following the devastating 2021 atmospheric river. Taking the interconnected approach to housing challenges acknowledged and developed (in-part) during the T'Sou-ke Housing Solutions Lab, the housing projects were used as a leverage point to support the Nation in meeting other elements of their self-directed visions for their communities. Other considerations included: cultural revitalization, educational outcomes for children, and capacity development and vocational training. In addition, the social return on investment (SROI) created by investing into improved housing for Indigenous peoples was briefly explored to help build the economic case for the project. This SROI suggests that investments into improved housing conditions for Indigenous peoples are not merely fiscal expenditures to the government. They could be seen as strategic, long-term investments into societal well-being that are both fiscally and morally responsible.

Successes of the projects include integration of cultural elements into project delivery, improved resiliency of the partner Nations to flooding and earthquakes, implementation of resilient construction methods that achieve Step-Code 5 energy performance, diversification of construction supply chains,

the development of a significant Nation-directed vocational training program, and improvement of over-crowding in homes (which may lead to long-term socio-economic improvements for children).

In the process of implementing this framework in practice, several challenges and pitfalls were identified. This has helped the IET to improve its services and will lead to a more robust solution concept that can be scaled to other RJC offices across Canada.

Future work will include ground-truthing the Social Return on Investment figures cited by the Aboriginal Housing Management Association to build the case for improving housing conditions in Indigenous Nations across Canada as a fiscally, ethically, and economically responsible means of reducing government spending on social programs. Metrics could include tracking changes in:

- Conditions and incidence of overcrowding in the Nations.
- Physical and mental health outcomes.
- Childhood educational attainment.
- Childhood behavioral challenges as reported by public schools.
- Sense of community and identity.
- Change in discretionary spending income.

In addition, the successes and challenges from the IET will be captured and scaled to other engineering offices in Canada to provide service to additional Indigenous Nations.

Addressing housing challenges in Indigenous communities requires a shift away from consultant driven approaches to ones that are community-centered, culturally informed, and aligned with the worldviews and values of the communities they serve. The work of the T'Sou-ke Housing Solutions Lab presents some potential solutions that could be scaled to other Indigenous communities in Canada.

By continuing to scale and ground these innovations, we contribute not only to supporting the resolution of the housing crisis faced by so many Indigenous communities, but also the broader goals of reconciliation in Canada. This is the antithesis to the “housing as a means of assimilation” approach to housing that the Canadian government and church institutions implemented in the late 1800s . Through meaningful collaboration, relationship development, and the mutual respect of Western and Indigenous worldviews and knowledge systems, housing projects can be leveraged as a powerful tool for reconciliation, healing, empowerment, and regenerative community building and rebuilding.

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Appendix A: Pre-Semester EQi 2.0 Inventory

EQ-i 2.0
assess. predict. perform.

My EI Report

Student Comprehensive

[redacted]

[redacted]

EITC | The Emotional Intelligence Training Company Inc.
Know. Engage. Lead.

Emotional Intelligence can contribute to academic, professional, and personal success!

Want to know more?

Read on to learn how you can use your strengths, and improve your weaknesses, to achieve the most in your academic and personal life.

MHS

Understanding Your Report

Welcome to the EQ-i 2.0 for Higher Education. The content of this report is intended to help you better understand how your emotional and social functioning impacts your academic, professional and personal performance. It is designed to help you objectively identify your emotional intelligence (EI) in terms of fifteen specific EI skills. In each of the fifteen skills, you will see your result and the implications your performance has on your school life and future career.

Emotional Intelligence and Success

Have you ever considered who among your classmates and friends will go on to achieve major life success? Who will create and lead companies of their own, or become prominent leaders in their community? What criteria do you consider: their intelligence, education, street smarts, charisma, good luck? While it would be nice to have a crystal ball to look into the future, what we do understand now is that cognitive intelligence is not the only predictor of life success; emotional intelligence plays a very big role too.

That is why some of the students who will achieve great heights are honing their teamwork skills through sports, gaining empathy by engaging in community service and refining leadership skills by serving as student leaders. EQ and IQ are different things, and EQ, unlike IQ, can be developed and enhanced.

A whole body of research shows that emotional intelligence is key to student success, both in terms of achieving higher grades and better study habits, but also in forming long lasting relationships and navigating the increased demands of student life.

Getting the Most out of Your Report

1. Take notes as you read your results. Write down what you agree with or findings you want to reflect on later.
2. Pick 2-3 areas that you wish to focus on strengthening. These areas can be existing strengths to leverage or lower scoring areas that need to be bolstered.
3. Choose strategies for development that you wish to try out. These are listed next to each EQ-i 2.0 subscale. Think of ways you can develop your skills in your classwork, assignments, internships/part-time job or with your close relationships.
4. All subscales are related to leadership behaviors; reflect on how you can leverage your EI skills in student leadership roles.

EQ-i 2.0 Model of Emotional Intelligence

SELF-PERCEPTION

Self-Regard is respecting oneself while understanding and accepting one's strengths and weaknesses. Self-Regard is often associated with feelings of inner strength and self-confidence.

Self-Actualization is the willingness to persistently try to improve oneself and engage in the pursuit of personally relevant and meaningful objectives that lead to a rich and enjoyable life.

Emotional Self-Awareness includes recognizing and understanding one's own emotions. This includes the ability to differentiate between subtleties in one's own emotions while understanding the cause of these emotions and the impact they have on one's own thoughts and actions and those of others.

STRESS MANAGEMENT

Flexibility is adapting emotions, thoughts and behaviors to unfamiliar, unpredictable, and dynamic circumstances or ideas.

Stress Tolerance involves coping with stressful or difficult situations and believing that one can manage or influence situations in a positive manner.

Optimism is an indicator of one's positive attitude and outlook on life. It involves remaining hopeful and resilient, despite occasional setbacks.

SELF-EXPRESSION

Emotional Expression is openly expressing one's feelings verbally and non-verbally.

Assertiveness involves communicating feelings, beliefs and thoughts openly, and defending personal rights and values in a socially acceptable, non-offensive, and non-destructive manner.

Independence is the ability to be self directed and free from emotional dependency on others. Decision-making, planning, and daily tasks are completed autonomously.

DECISION MAKING

Problem Solving is the ability to find solutions to problems in situations where emotions are involved. Problem solving includes the ability to understand how emotions impact decision making.

Reality Testing is the capacity to remain objective by seeing things as they really are. This capacity involves recognizing when emotions or personal bias can cause one to be less objective.

Impulse Control is the ability to resist or delay an impulse, drive or temptation to act and involves avoiding rash behaviors and decision making.

INTERPERSONAL

Interpersonal Relationships refers to the skill of developing and maintaining mutually satisfying relationships that are characterized by trust and compassion.

Empathy is recognizing, understanding, and appreciating how other people feel. Empathy involves being able to articulate your understanding of another's perspective and behaving in a way that respects others' feelings.

Social Responsibility is willingly contributing to society, to one's social groups, and generally to the welfare of others. Social Responsibility involves acting responsibly, having social consciousness, and showing concern for the greater community.

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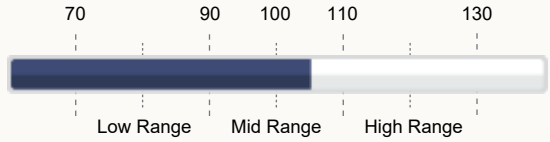
Overview

Total EI

105



Self-Perception Composite

106

Self-Regard
Respecting oneself; Confidence

94

Self-Actualization
Pursuit of meaning; Self-improvement

112

Emotional Self-Awareness
Understanding own emotions

111

Self-Expression Composite

102

Emotional Expression
Constructive expression of emotions

112

Assertiveness
Communicating feelings, beliefs; Non-offensive

85

Independence
Self-directed; Free from emotional dependency

101

Interpersonal Composite

103

Interpersonal Relationships
Mutually satisfying relationships

106

Empathy
Understanding, appreciating how others feel

96

Social Responsibility
Social conciousness; Helpful

107

Decision Making Composite

111

Problem Solving
Find solutions when emotions are involved

100

Reality Testing
Objective; See things as they really are

103

Impulse Control
Resist or delay impulse to act

122

Stress Management Composite

99

Flexibility
Adapting emotions, thoughts and behaviors

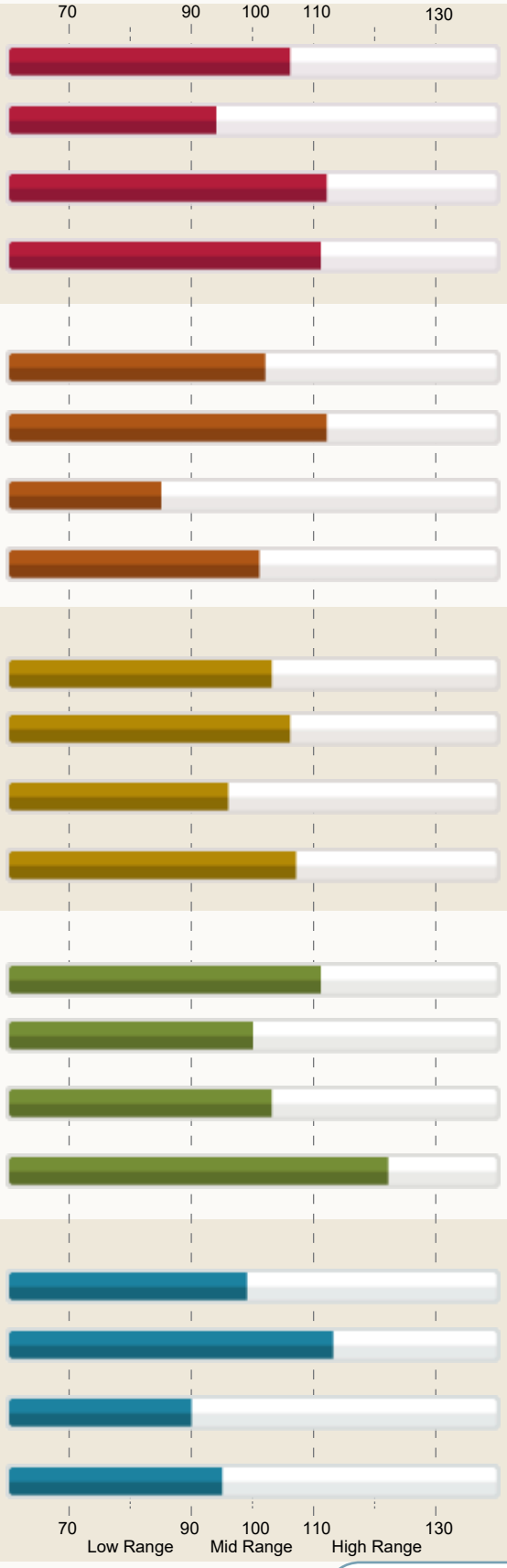
113

Stress Tolerance
Coping with stressful situations

90

Optimism
Positive attitude and outlook on life

95



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EQ-i 2.0
assess. predict. perform.

My EI Report

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Overview

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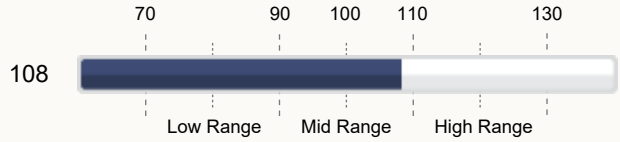
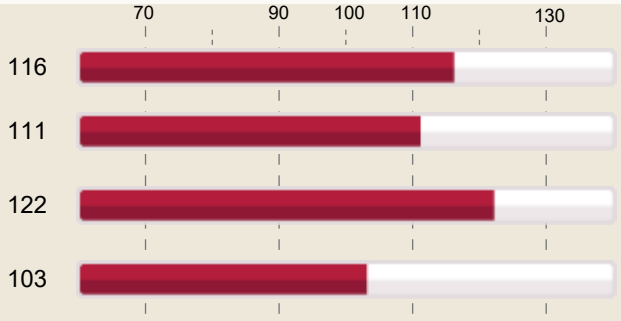


Self-Perception Composite

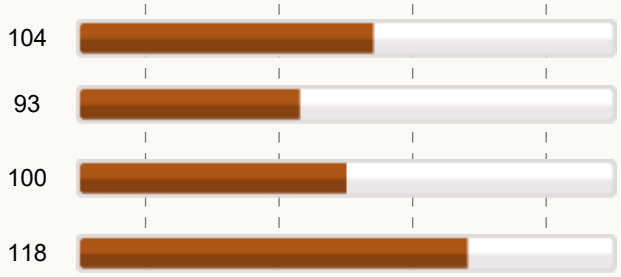


Self-Regard
Respecting oneself; Confidence

Self-Actualization
Pursuit of meaning; Self-improvement

Emotional Self-Awareness
Understanding own emotions

Self-Expression Composite

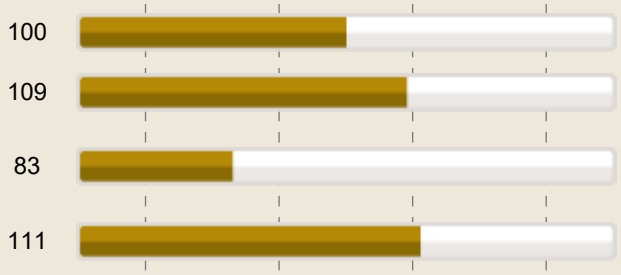


Emotional Expression
Constructive expression of emotions

Assertiveness
Communicating feelings, beliefs; Non-offensive

Independence
Self-directed; Free from emotional dependency

Interpersonal Composite

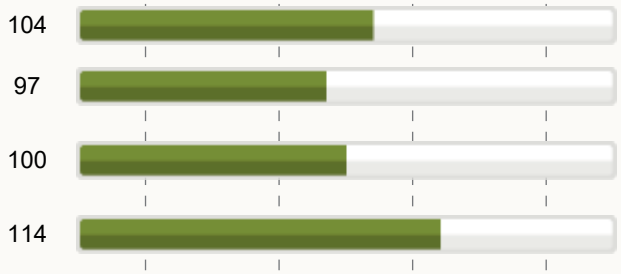


Interpersonal Relationships
Mutually satisfying relationships

Empathy
Understanding, appreciating how others feel

Social Responsibility
Social conciousness; Helpful

Decision Making Composite

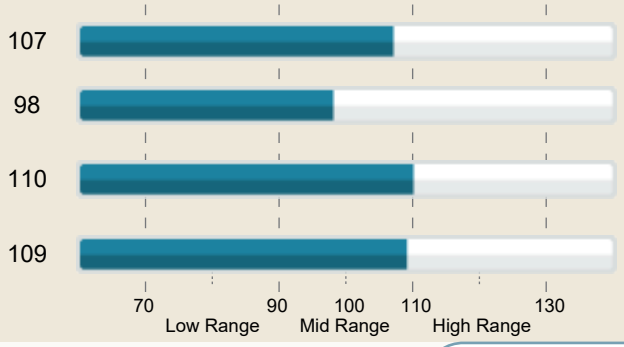


Problem Solving
Find solutions when emotions are involved

Reality Testing
Objective; See things as they really are

Impulse Control
Resist or delay impulse to act

Stress Management Composite



Flexibility
Adapting emotions, thoughts and behaviors

Stress Tolerance
Coping with stressful situations

Optimism
Positive attitude and outlook on life

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EQ-i 2.0
assess. predict. perform.

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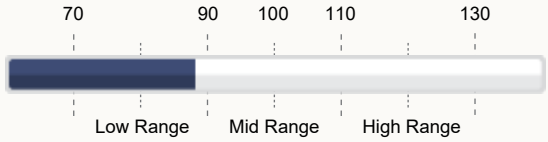
Total EI

88



Self-Perception Composite

73

Self-Regard
Respecting oneself; Confidence

72

Self-Actualization
Pursuit of meaning; Self-improvement

88

Emotional Self-Awareness
Understanding own emotions

71

Self-Expression Composite

83

Emotional Expression
Constructive expression of emotions

68

Assertiveness
Communicating feelings, beliefs; Non-offensive

100

Independence
Self-directed; Free from emotional dependency

98

Interpersonal Composite

96

Interpersonal Relationships
Mutually satisfying relationships

95

Empathy
Understanding, appreciating how others feel

91

Social Responsibility
Social conciousness; Helpful

107

Decision Making Composite

86

Problem Solving
Find solutions when emotions are involved

94

Reality Testing
Objective; See things as they really are

67

Impulse Control
Resist or delay impulse to act

102

Stress Management Composite

112

Flexibility
Adapting emotions, thoughts and behaviors

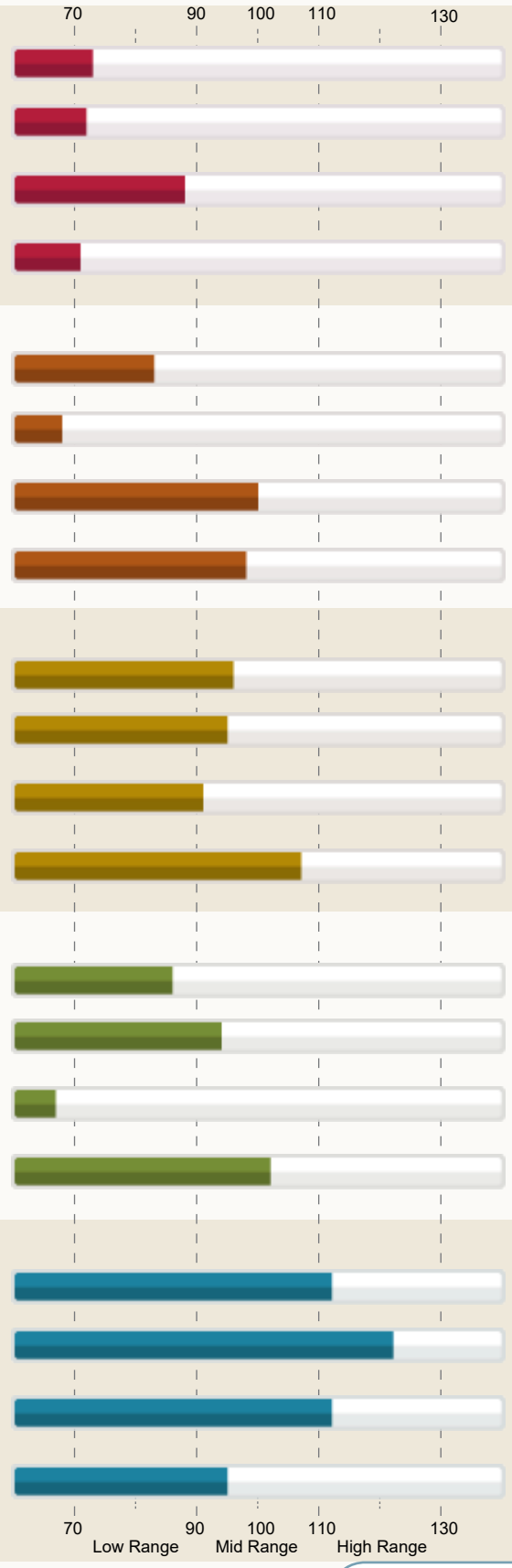
122

Stress Tolerance
Coping with stressful situations

112

Optimism
Positive attitude and outlook on life

95



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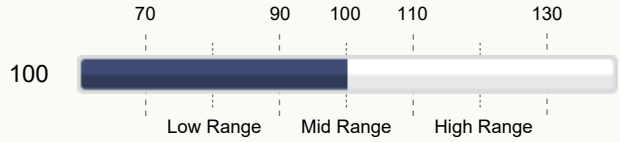
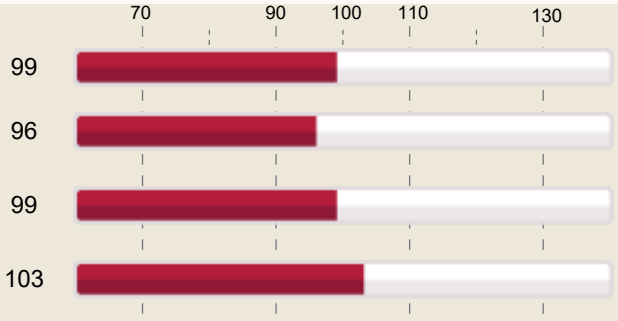


Self-Perception Composite

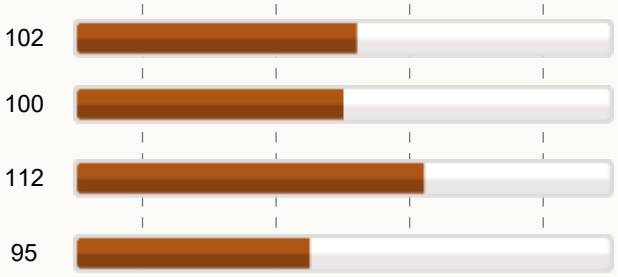


Self-Regard
Respecting oneself; Confidence

Self-Actualization
Pursuit of meaning; Self-improvement

Emotional Self-Awareness
Understanding own emotions

Self-Expression Composite

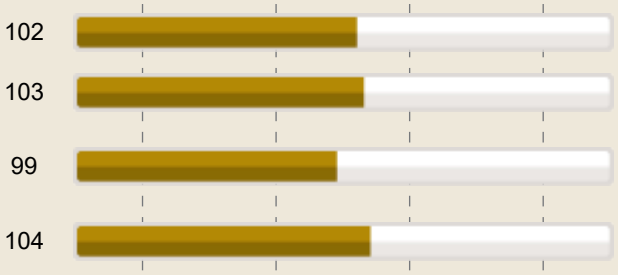


Emotional Expression
Constructive expression of emotions

Assertiveness
Communicating feelings, beliefs; Non-offensive

Independence
Self-directed; Free from emotional dependency

Interpersonal Composite

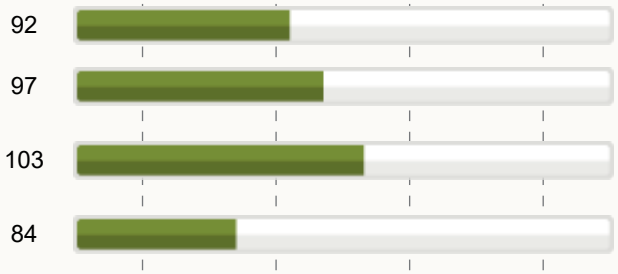


Interpersonal Relationships
Mutually satisfying relationships

Empathy
Understanding, appreciating how others feel

Social Responsibility
Social conciousness; Helpful

Decision Making Composite

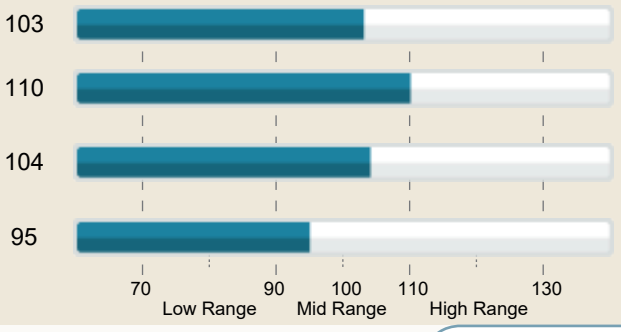


Problem Solving
Find solutions when emotions are involved

Reality Testing
Objective; See things as they really are

Impulse Control
Resist or delay impulse to act

Stress Management Composite



Flexibility
Adapting emotions, thoughts and behaviors

Stress Tolerance
Coping with stressful situations

Optimism
Positive attitude and outlook on life

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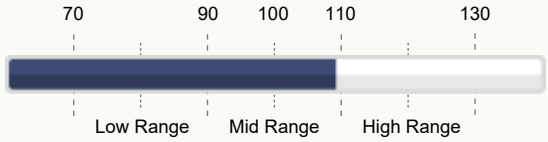
Overview

Total EI

109



Self-Perception Composite

117

Self-Regard
Respecting oneself; Confidence

108

Self-Actualization
Pursuit of meaning; Self-improvement

120

Emotional Self-Awareness
Understanding own emotions

114

Self-Expression Composite

108

Emotional Expression
Constructive expression of emotions

90

Assertiveness
Communicating feelings, beliefs; Non-offensive

115

Independence
Self-directed; Free from emotional dependency

118

Interpersonal Composite

99

Interpersonal Relationships
Mutually satisfying relationships

112

Empathy
Understanding, appreciating how others feel

91

Social Responsibility
Social conciousness; Helpful

93

Decision Making Composite

114

Problem Solving
Find solutions when emotions are involved

111

Reality Testing
Objective; See things as they really are

125

Impulse Control
Resist or delay impulse to act

99

Stress Management Composite

101

Flexibility
Adapting emotions, thoughts and behaviors

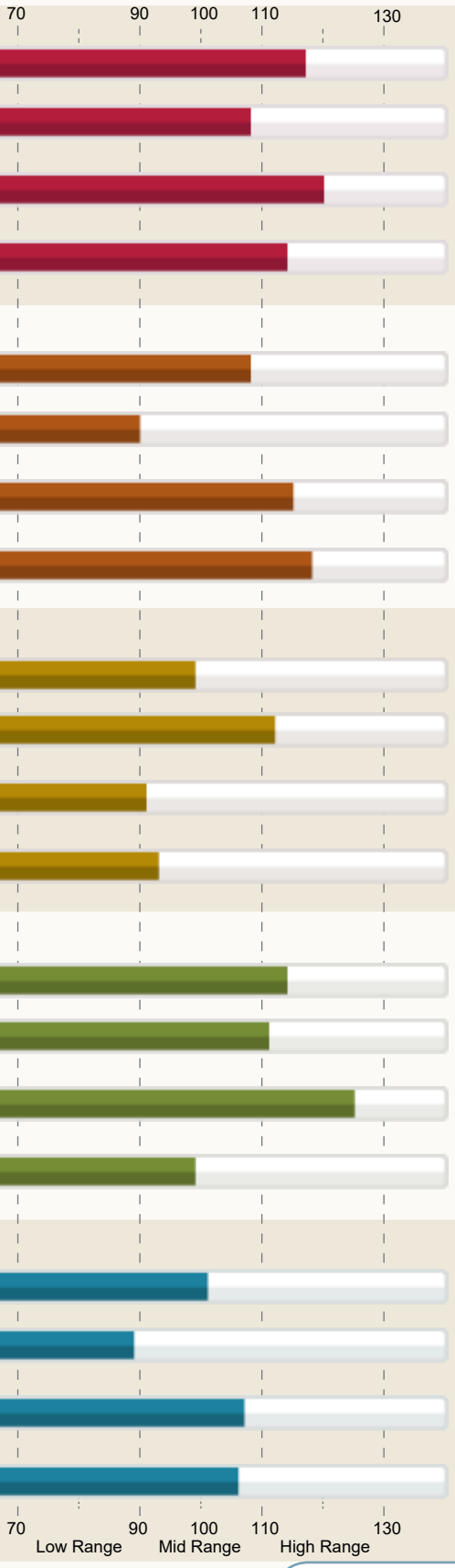
89

Stress Tolerance
Coping with stressful situations

107

Optimism
Positive attitude and outlook on life

106



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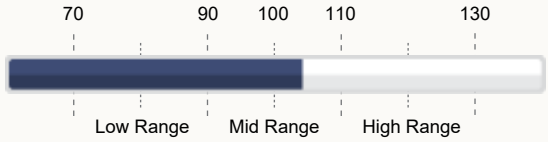
Total EI

104



Self-Perception Composite

100

Self-Regard
Respecting oneself; Confidence

94

Self-Actualization
Pursuit of meaning; Self-improvement

104

Emotional Self-Awareness
Understanding own emotions

103

Self-Expression Composite

107

Emotional Expression
Constructive expression of emotions

112

Assertiveness
Communicating feelings, beliefs; Non-offensive

93

Independence
Self-directed; Free from emotional dependency

106

Interpersonal Composite

97

Interpersonal Relationships
Mutually satisfying relationships

106

Empathy
Understanding, appreciating how others feel

99

Social Responsibility
Social conciousness; Helpful

85

Decision Making Composite

108

Problem Solving
Find solutions when emotions are involved

114

Reality Testing
Objective; See things as they really are

89

Impulse Control
Resist or delay impulse to act

114

Stress Management Composite

106

Flexibility
Adapting emotions, thoughts and behaviors

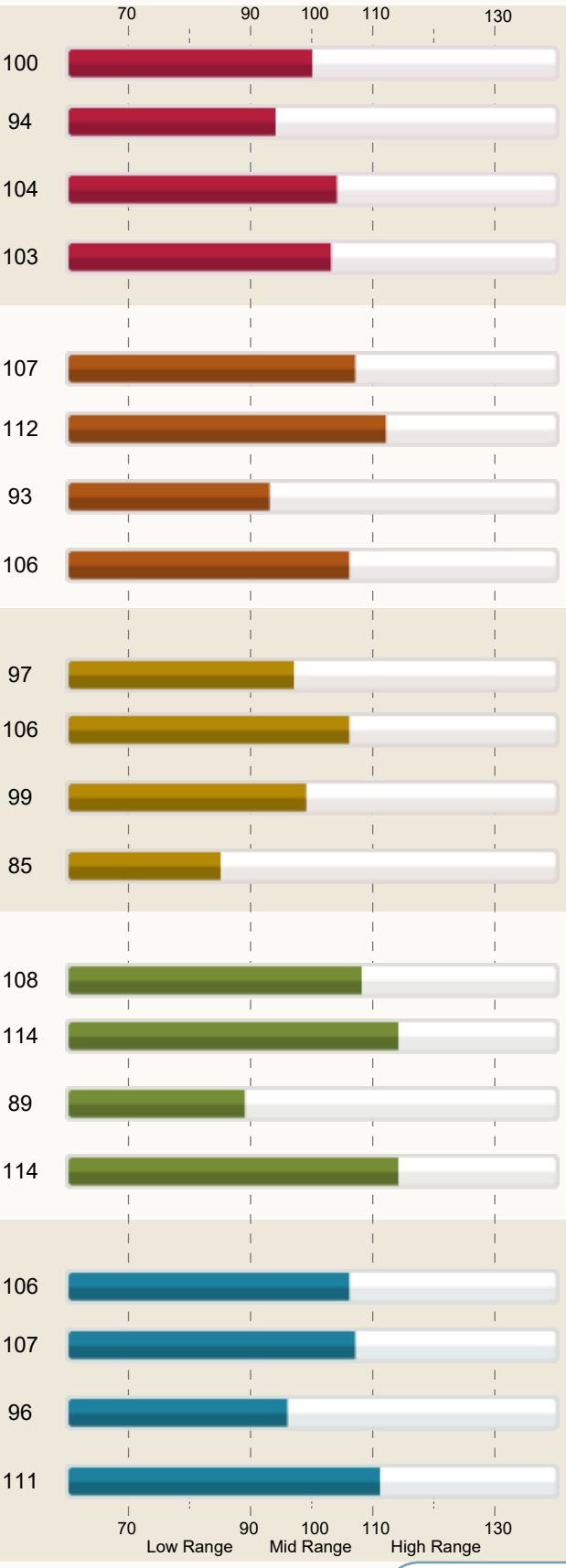
107

Stress Tolerance
Coping with stressful situations

96

Optimism
Positive attitude and outlook on life

111



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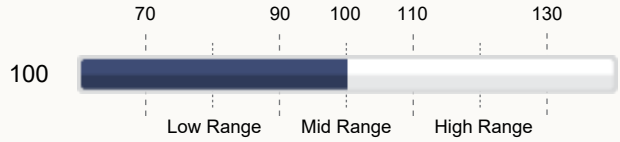


Self-Perception Composite

83

Self-Regard
Respecting oneself; Confidence

103

Self-Actualization
Pursuit of meaning; Self-improvement

75

Emotional Self-Awareness
Understanding own emotions

75

Self-Expression Composite

94

Emotional Expression
Constructive expression of emotions

95

Assertiveness
Communicating feelings, beliefs; Non-offensive

89

Independence
Self-directed; Free from emotional dependency

101

Interpersonal Composite

99

Interpersonal Relationships
Mutually satisfying relationships

103

Empathy
Understanding, appreciating how others feel

99

Social Responsibility
Social conciousness; Helpful

93

Decision Making Composite

106

Problem Solving
Find solutions when emotions are involved

114

Reality Testing
Objective; See things as they really are

74

Impulse Control
Resist or delay impulse to act

120

Stress Management Composite

118

Flexibility
Adapting emotions, thoughts and behaviors

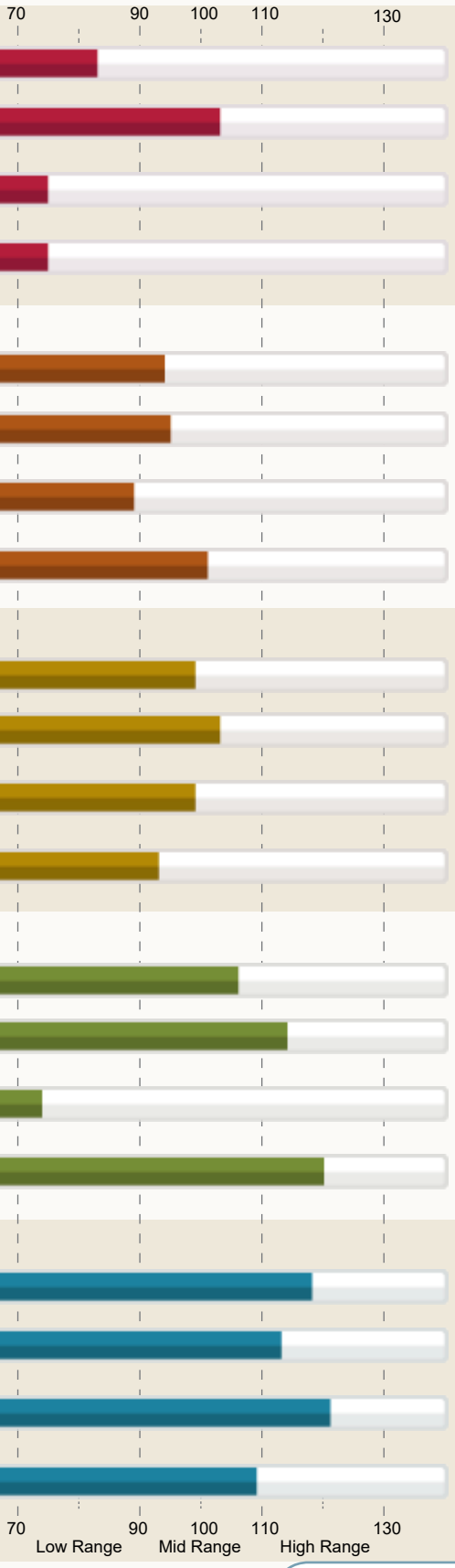
113

Stress Tolerance
Coping with stressful situations

121

Optimism
Positive attitude and outlook on life

109



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Total EI

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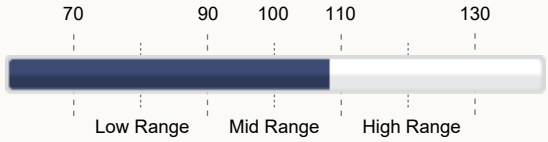


Self-Perception Composite

107

Self-Regard
Respecting oneself; Confidence

111

Self-Actualization
Pursuit of meaning; Self-improvement

107

Emotional Self-Awareness
Understanding own emotions

96

Self-Expression Composite

109

Emotional Expression
Constructive expression of emotions

105

Assertiveness
Communicating feelings, beliefs; Non-offensive

100

Independence
Self-directed; Free from emotional dependency

115

Interpersonal Composite

105

Interpersonal Relationships
Mutually satisfying relationships

103

Empathy
Understanding, appreciating how others feel

104

Social Responsibility
Social conciousness; Helpful

104

Decision Making Composite

96

Problem Solving
Find solutions when emotions are involved

100

Reality Testing
Objective; See things as they really are

92

Impulse Control
Resist or delay impulse to act

99

Stress Management Composite

115

Flexibility
Adapting emotions, thoughts and behaviors

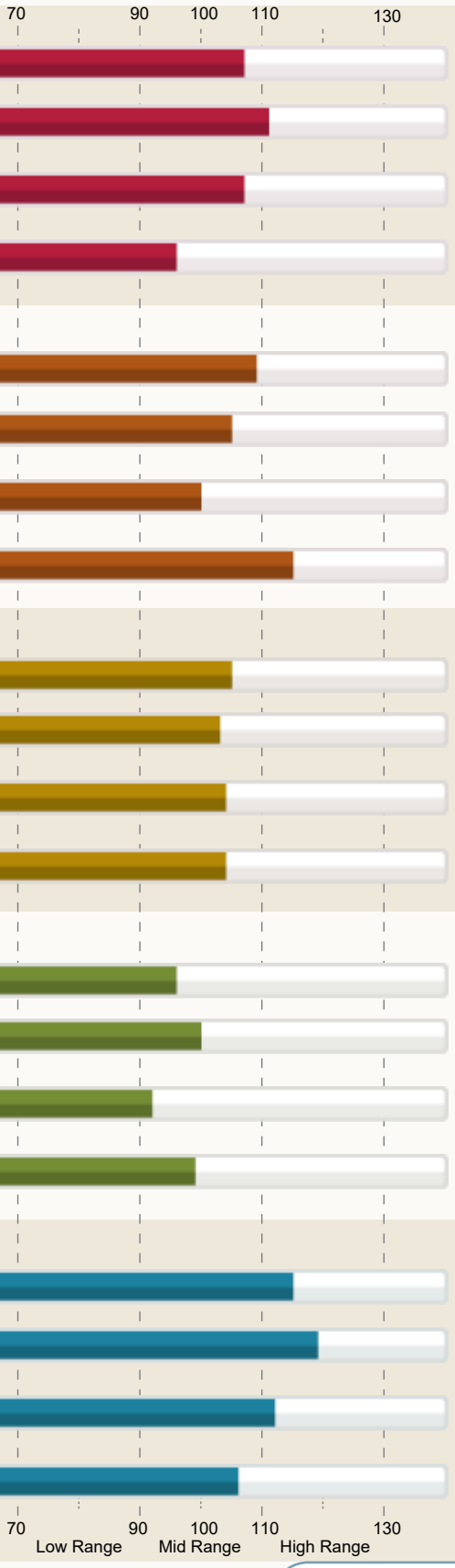
119

Stress Tolerance
Coping with stressful situations

112

Optimism
Positive attitude and outlook on life

106



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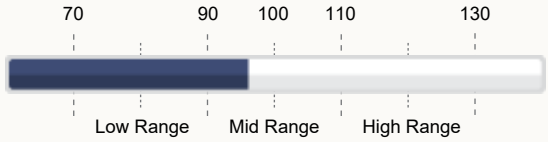
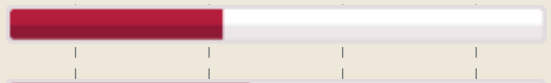


Self-Perception Composite

95

Self-Regard
Respecting oneself; Confidence

92



Self-Actualization
Pursuit of meaning; Self-improvement

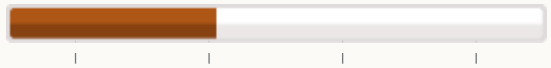
96

Emotional Self-Awareness
Understanding own emotions

103

Self-Expression Composite

91



Emotional Expression
Constructive expression of emotions

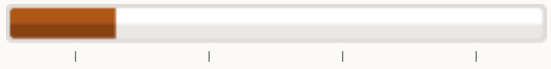
110

Assertiveness
Communicating feelings, beliefs; Non-offensive

89

Independence
Self-directed; Free from emotional dependency

76

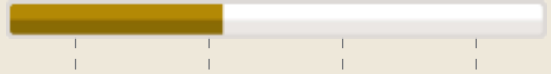


Interpersonal Composite

97

Interpersonal Relationships
Mutually satisfying relationships

92



Empathy
Understanding, appreciating how others feel

107

Social Responsibility
Social conciousness; Helpful

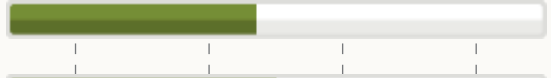
93

Decision Making Composite

103

Problem Solving
Find solutions when emotions are involved

97



Reality Testing
Objective; See things as they really are

100

Impulse Control
Resist or delay impulse to act

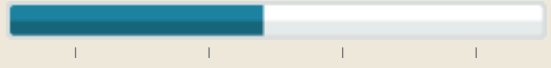
111

Stress Management Composite

96

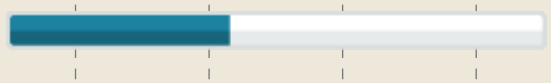
Flexibility
Adapting emotions, thoughts and behaviors

98



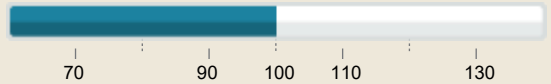
Stress Tolerance
Coping with stressful situations

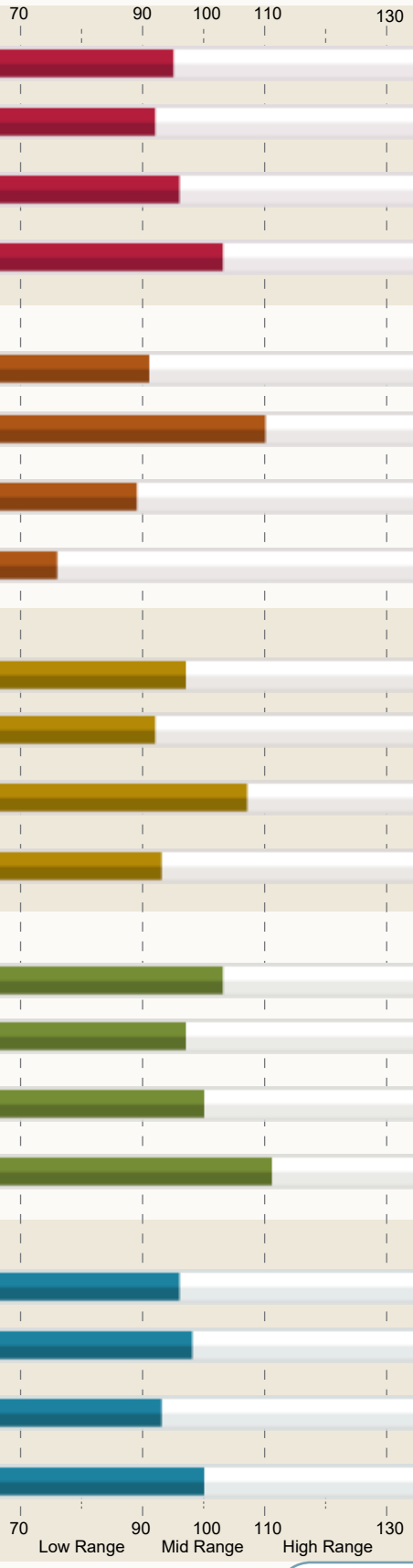
93



Optimism
Positive attitude and outlook on life

100





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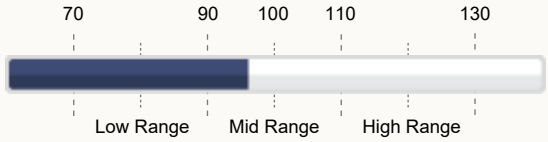
Overview

Total EI

96



Self-Perception Composite

106

Self-Regard
Respecting oneself; Confidence

108

Self-Actualization
Pursuit of meaning; Self-improvement

112

Emotional Self-Awareness
Understanding own emotions

89

Self-Expression Composite

82

Emotional Expression
Constructive expression of emotions

80

Assertiveness
Communicating feelings, beliefs; Non-offensive

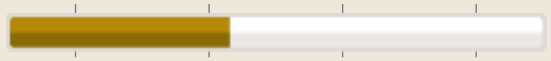
89

Independence
Self-directed; Free from emotional dependency

90

Interpersonal Composite

93



Interpersonal Relationships
Mutually satisfying relationships

106

Empathy
Understanding, appreciating how others feel

83

Social Responsibility
Social conciousness; Helpful

93

Decision Making Composite

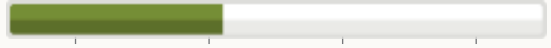
90

Problem Solving
Find solutions when emotions are involved

83

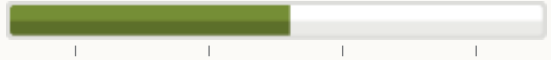
Reality Testing
Objective; See things as they really are

92



Impulse Control
Resist or delay impulse to act

102



Stress Management Composite

111

Flexibility
Adapting emotions, thoughts and behaviors

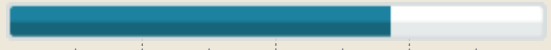
104

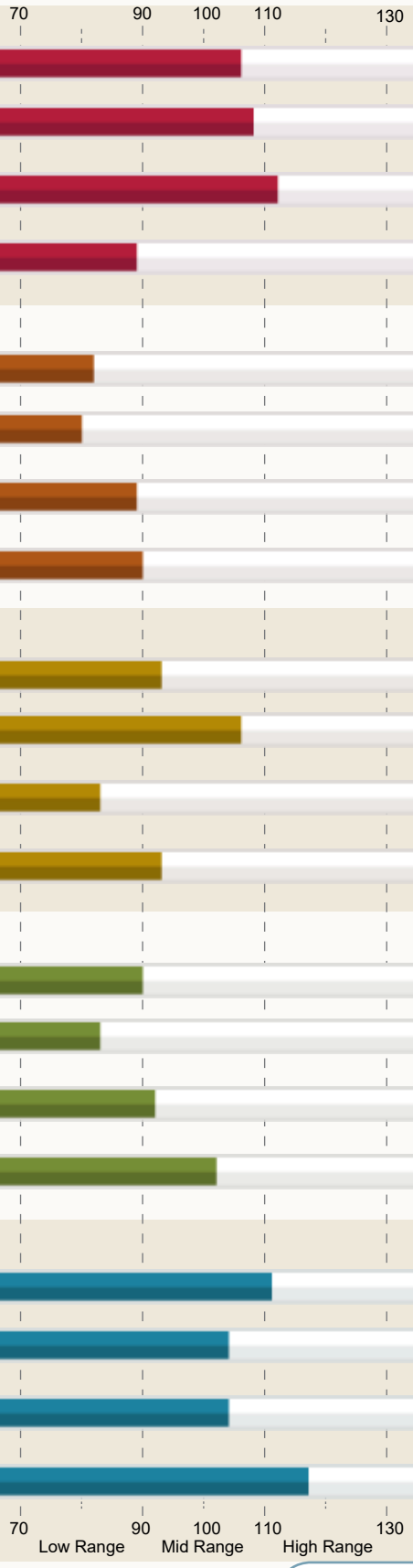
Stress Tolerance
Coping with stressful situations

104

Optimism
Positive attitude and outlook on life

117





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EQ-i 2.0
assess. predict. perform.

My EI Report

Student Comprehensive

[redacted]

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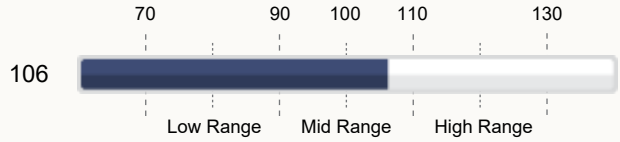
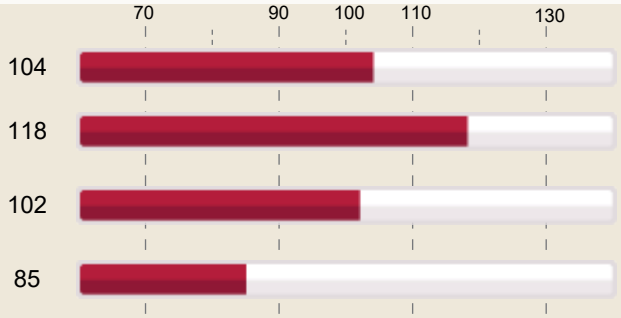
Overview

Total EI



Self-Perception Composite

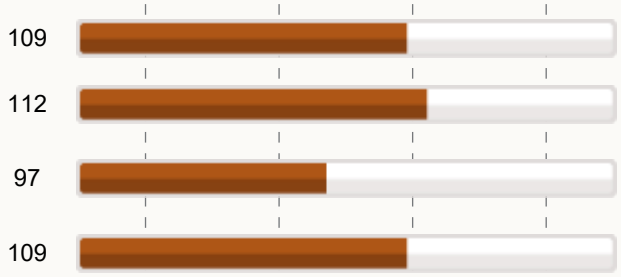


Self-Regard
Respecting oneself; Confidence

Self-Actualization
Pursuit of meaning; Self-improvement

Emotional Self-Awareness
Understanding own emotions

Self-Expression Composite

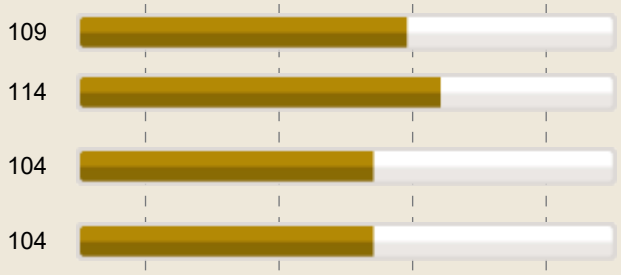


Emotional Expression
Constructive expression of emotions

Assertiveness
Communicating feelings, beliefs; Non-offensive

Independence
Self-directed; Free from emotional dependency

Interpersonal Composite

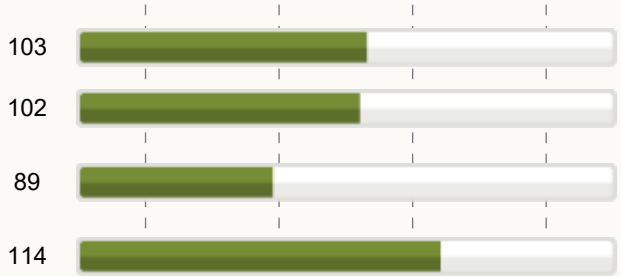


Interpersonal Relationships
Mutually satisfying relationships

Empathy
Understanding, appreciating how others feel

Social Responsibility
Social conciousness; Helpful

Decision Making Composite

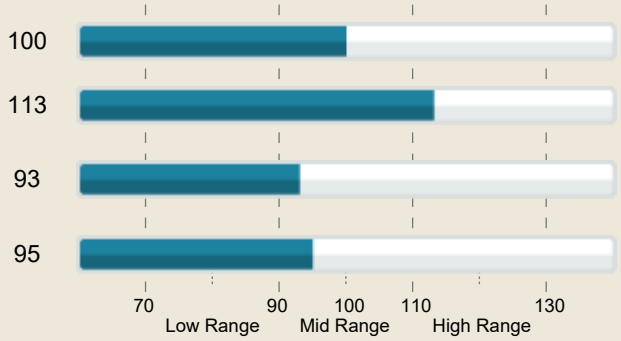


Problem Solving
Find solutions when emotions are involved

Reality Testing
Objective; See things as they really are

Impulse Control
Resist or delay impulse to act

Stress Management Composite



Flexibility
Adapting emotions, thoughts and behaviors

Stress Tolerance
Coping with stressful situations

Optimism
Positive attitude and outlook on life

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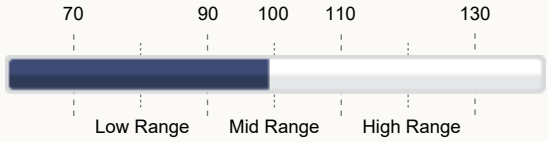
99



Self-Perception Composite

85

Self-Regard
Respecting oneself; Confidence

82

Self-Actualization
Pursuit of meaning; Self-improvement

96

Emotional Self-Awareness
Understanding own emotions

85

Self-Expression Composite

93

Emotional Expression
Constructive expression of emotions

93

Assertiveness
Communicating feelings, beliefs; Non-offensive

85

Independence
Self-directed; Free from emotional dependency

104

Interpersonal Composite

96

Interpersonal Relationships
Mutually satisfying relationships

98

Empathy
Understanding, appreciating how others feel

88

Social Responsibility
Social conciousness; Helpful

107

Decision Making Composite

107

Problem Solving
Find solutions when emotions are involved

116

Reality Testing
Objective; See things as they really are

92

Impulse Control
Resist or delay impulse to act

105

Stress Management Composite

114

Flexibility
Adapting emotions, thoughts and behaviors

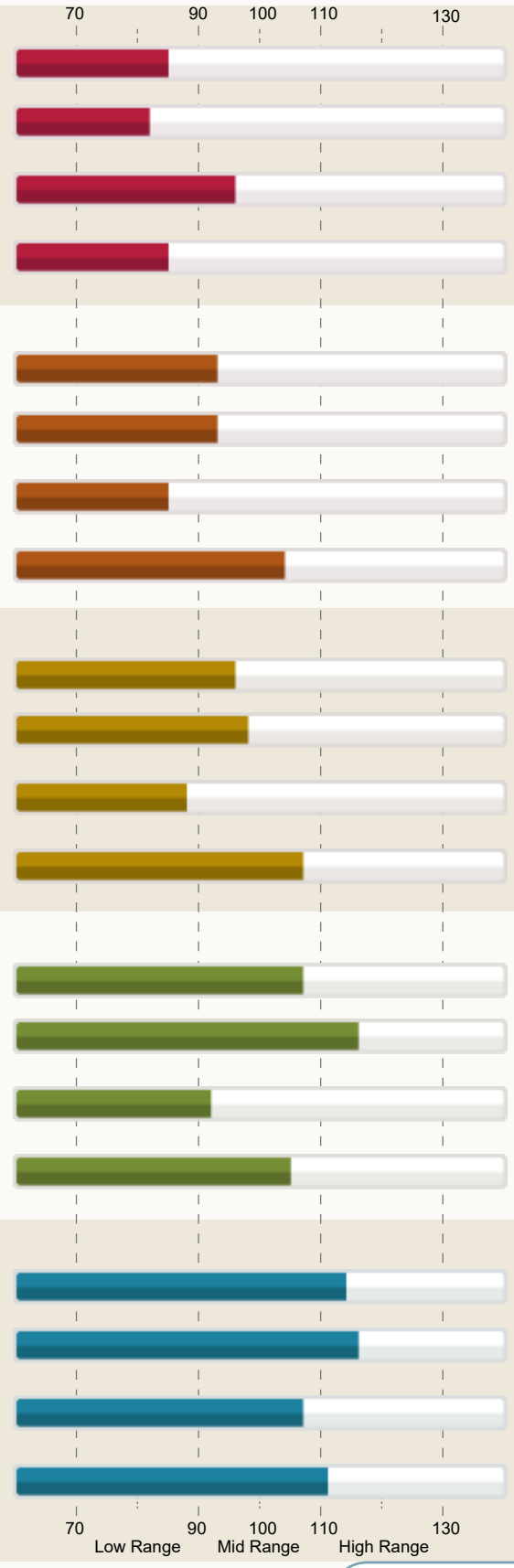
116

Stress Tolerance
Coping with stressful situations

107

Optimism
Positive attitude and outlook on life

111



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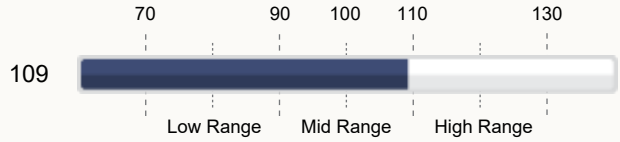
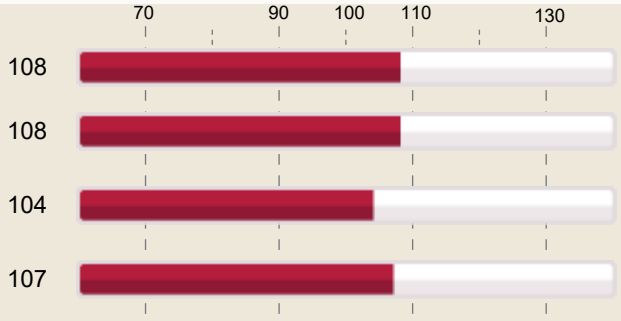


Self-Perception Composite



Self-Regard
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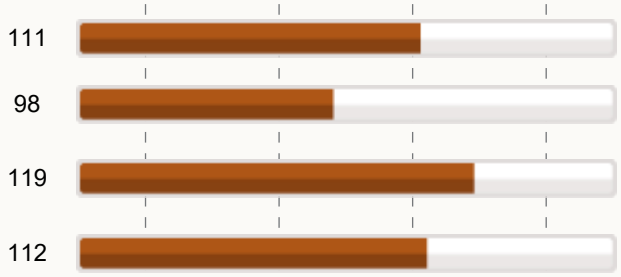
Understanding own emotions

Self-Expression Composite



Emotional Expression
Constructive expression of emotions

Assertiveness
Communicating feelings, beliefs; Non-offensive

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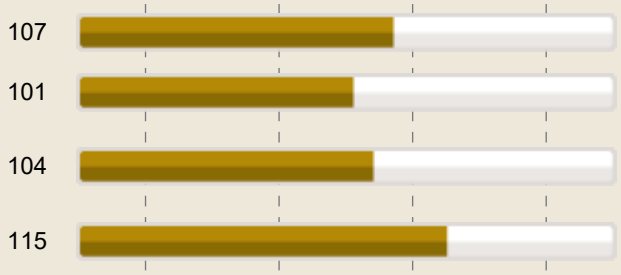
Self-directed; Free from emotional dependency

Interpersonal Composite

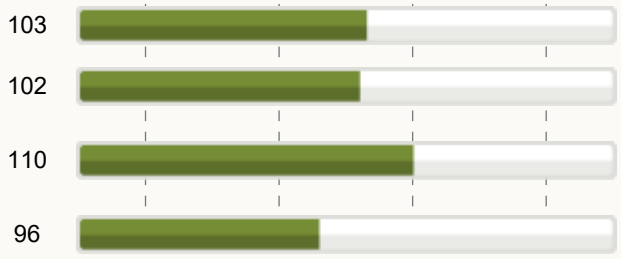


Interpersonal Relationships
Mutually satisfying relationships

Empathy
Understanding, appreciating how others feel

Social Responsibility
Social conciousness; Helpful

Decision Making Composite



Problem Solving
Find solutions when emotions are involved

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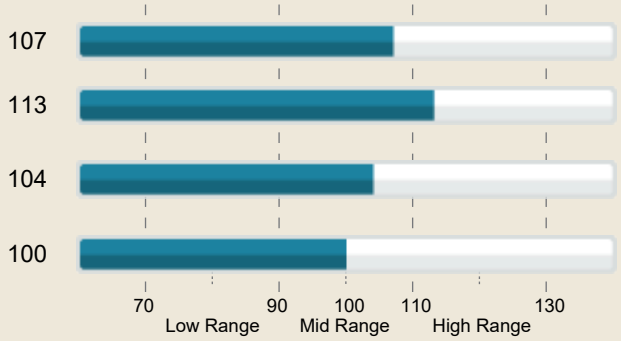
Stress Management Composite



Flexibility
Adapting emotions, thoughts and behaviors

Stress Tolerance
Coping with stressful situations

Optimism
Positive attitude and outlook on life

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EQ-i 2.0
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My EI Report

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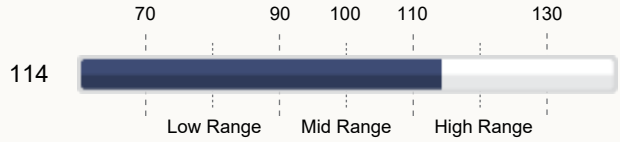
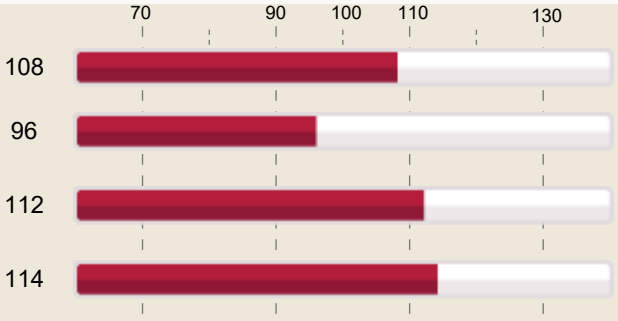


Self-Perception Composite

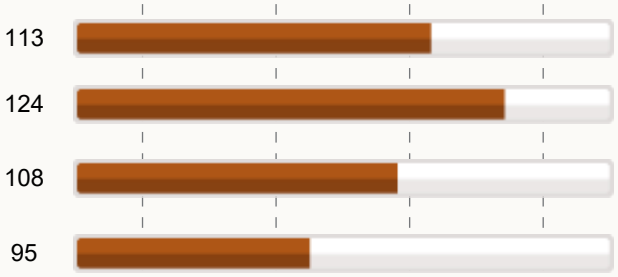


Self-Regard
Respecting oneself; Confidence

Self-Actualization
Pursuit of meaning; Self-improvement

Emotional Self-Awareness
Understanding own emotions

Self-Expression Composite



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Independence
Self-directed; Free from emotional dependency

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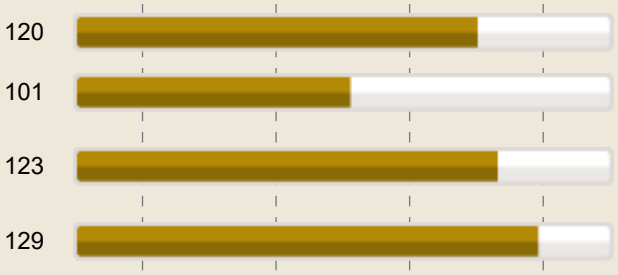
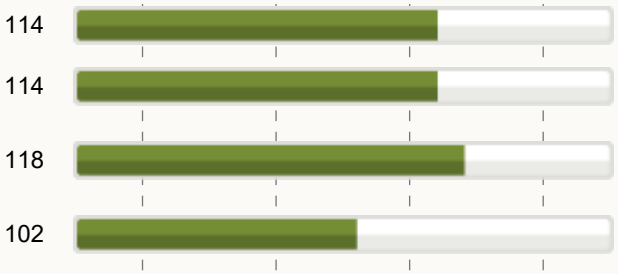


Interpersonal Relationships
Mutually satisfying relationships

Empathy
Understanding, appreciating how others feel

Social Responsibility
Social conciousness; Helpful

Decision Making Composite

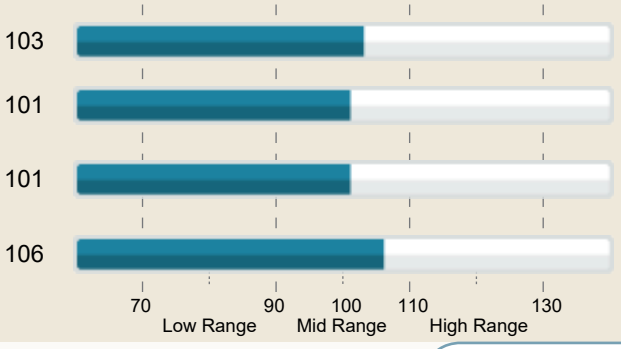


Problem Solving
Find solutions when emotions are involved

Reality Testing
Objective; See things as they really are

Impulse Control
Resist or delay impulse to act

Stress Management Composite



Flexibility
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Stress Tolerance
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EQ-i 2.0
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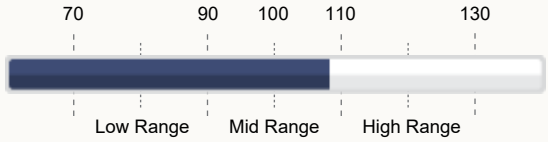
Overview

Total EI

108



Self-Perception Composite

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Self-Regard
Respecting oneself; Confidence

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Self-Actualization
Pursuit of meaning; Self-improvement

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Emotional Self-Awareness
Understanding own emotions

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Self-Expression Composite

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Emotional Expression
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Assertiveness
Communicating feelings, beliefs; Non-offensive

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Independence
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Interpersonal Relationships
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Social Responsibility
Social conciousness; Helpful

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Decision Making Composite

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Find solutions when emotions are involved

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Reality Testing
Objective; See things as they really are

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Resist or delay impulse to act

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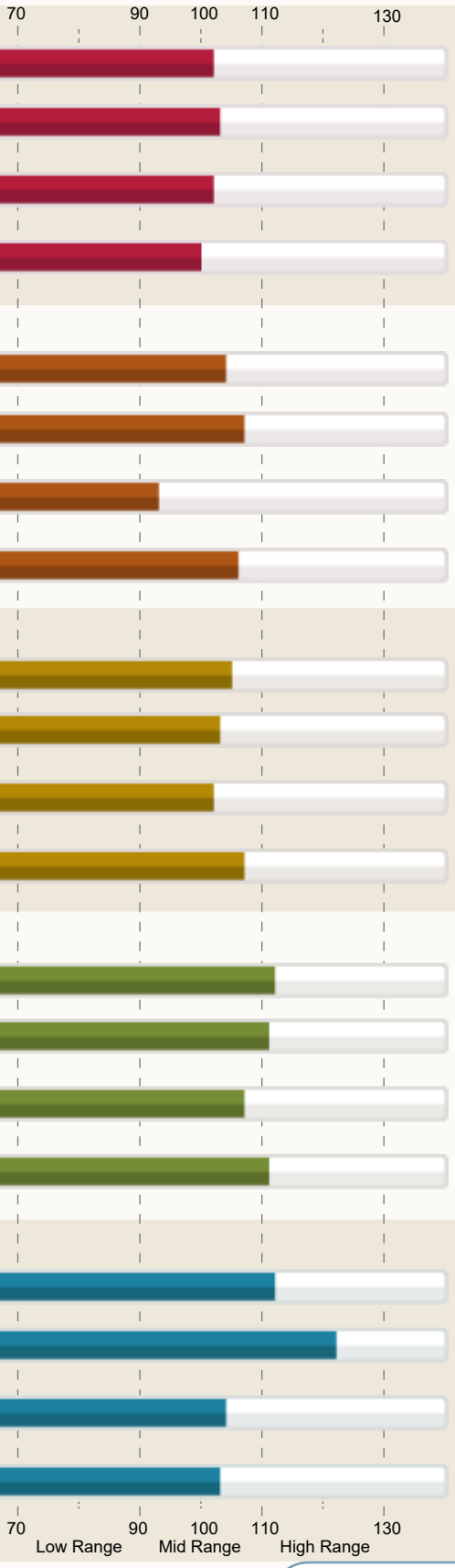

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Overview

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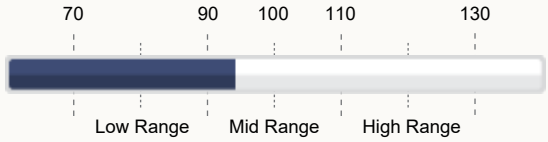
94



Self-Perception Composite

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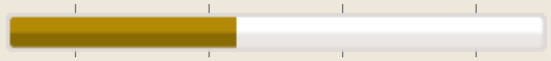

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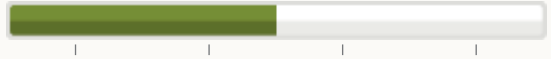
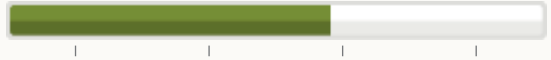


Reality Testing
Objective; See things as they really are

71

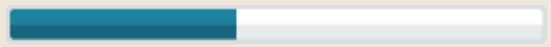
Impulse Control
Resist or delay impulse to act

108



Stress Management Composite

94



Flexibility
Adapting emotions, thoughts and behaviors

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Stress Tolerance
Coping with stressful situations

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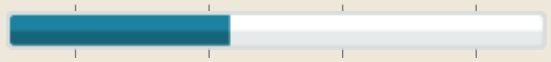
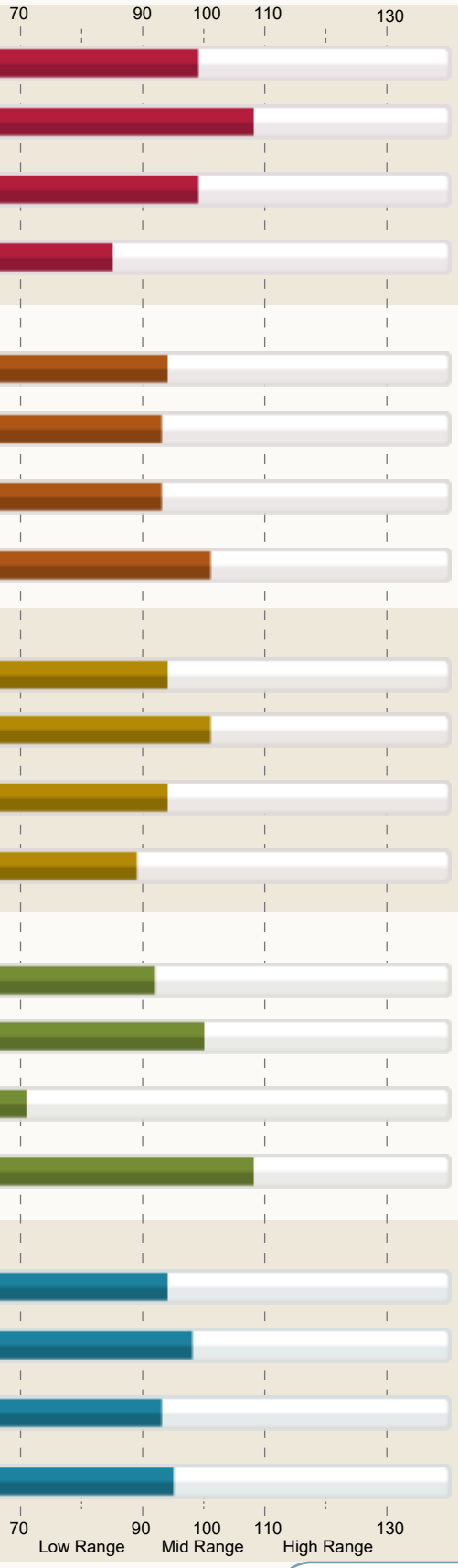


Optimism
Positive attitude and outlook on life

95



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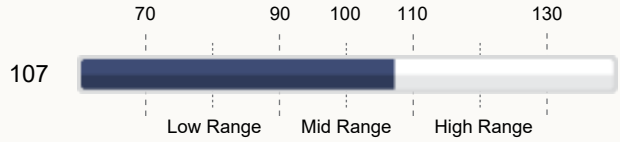
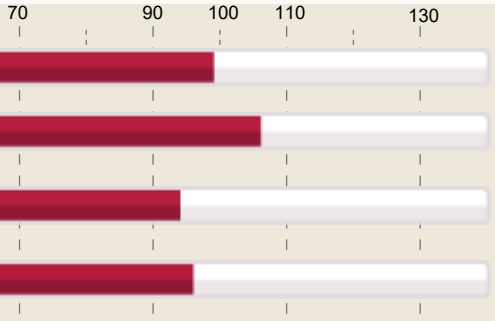


Self-Perception Composite



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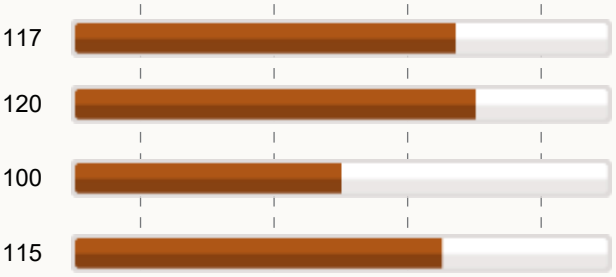
Pursuit of meaning; Self-improvement

Emotional Self-Awareness
Understanding own emotions

Self-Expression Composite



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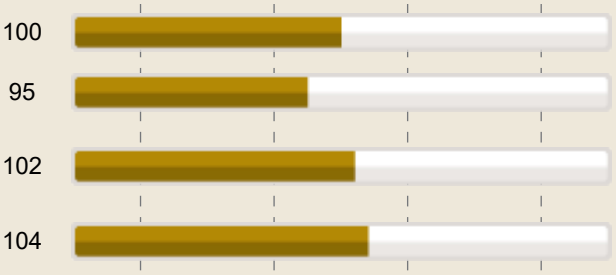

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Social conciousness; Helpful

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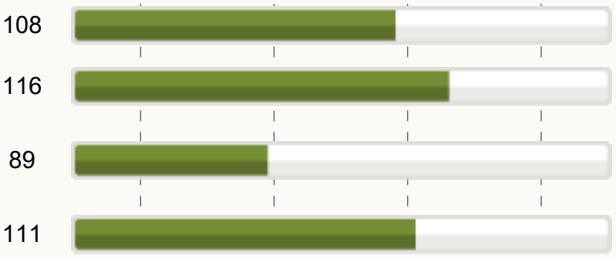

Problem Solving
Find solutions when emotions are involved

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Objective; See things as they really are

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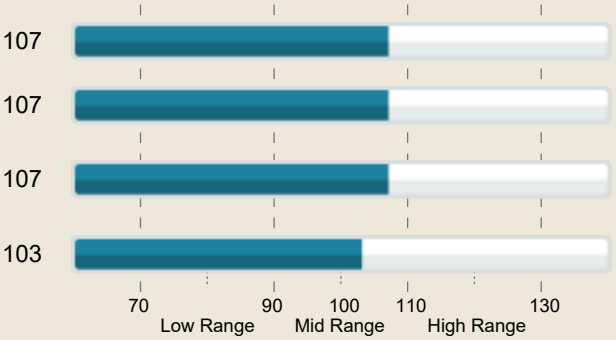
Resist or delay impulse to act

Stress Management Composite



Flexibility
Adapting emotions, thoughts and behaviors

Stress Tolerance
Coping with stressful situations

Optimism
Positive attitude and outlook on life

4994-95A3-7A61

Appendix B: Post-Semester EQi 2.0 Inventory

EQ-i 2.0
assess. predict. perform.

My EI Report

Student Comprehensive

[redacted]

[redacted]

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Understanding Your Report

Welcome to the EQ-i 2.0 for Higher Education. The content of this report is intended to help you better understand how your emotional and social functioning impacts your academic, professional and personal performance. It is designed to help you objectively identify your emotional intelligence (EI) in terms of fifteen specific EI skills. In each of the fifteen skills, you will see your result and the implications your performance has on your school life and future career.

Emotional Intelligence and Success

Have you ever considered who among your classmates and friends will go on to achieve major life success? Who will create and lead companies of their own, or become prominent leaders in their community? What criteria do you consider: their intelligence, education, street smarts, charisma, good luck? While it would be nice to have a crystal ball to look into the future, what we do understand now is that cognitive intelligence is not the only predictor of life success; emotional intelligence plays a very big role too.

That is why some of the students who will achieve great heights are honing their teamwork skills through sports, gaining empathy by engaging in community service and refining leadership skills by serving as student leaders. EQ and IQ are different things, and EQ, unlike IQ, can be developed and enhanced.

A whole body of research shows that emotional intelligence is key to student success, both in terms of achieving higher grades and better study habits, but also in forming long lasting relationships and navigating the increased demands of student life.

Getting the Most out of Your Report

1. Take notes as you read your results. Write down what you agree with or findings you want to reflect on later.

2. Pick 2-3 areas that you wish to focus on strengthening. These areas can be existing strengths to leverage or lower scoring areas that need to be bolstered.

3. Choose strategies for development that you wish to try out. These are listed next to each EQ-i 2.0 subscale. Think of ways you can develop your skills in your classwork, assignments, internships/part-time job or with your close relationships.

4. All subscales are related to leadership behaviors; reflect on how you can leverage your EI skills in student leadership roles.

EQ-i 2.0 Model of Emotional Intelligence

SELF-PERCEPTION

Self-Regard is respecting oneself while understanding and accepting one's strengths and weaknesses. Self-Regard is often associated with feelings of inner strength and self-confidence.

Self-Actualization is the willingness to persistently try to improve oneself and engage in the pursuit of personally relevant and meaningful objectives that lead to a rich and enjoyable life.

Emotional Self-Awareness includes recognizing and understanding one's own emotions. This includes the ability to differentiate between subtleties in one's own emotions while understanding the cause of these emotions and the impact they have on one's own thoughts and actions and those of others.

STRESS MANAGEMENT

Flexibility is adapting emotions, thoughts and behaviors to unfamiliar, unpredictable, and dynamic circumstances or ideas.

Stress Tolerance involves coping with stressful or difficult situations and believing that one can manage or influence situations in a positive manner.

Optimism is an indicator of one's positive attitude and outlook on life. It involves remaining hopeful and resilient, despite occasional setbacks.

SELF-EXPRESSION

Emotional Expression is openly expressing one's feelings verbally and non-verbally.

Assertiveness involves communicating feelings, beliefs and thoughts openly, and defending personal rights and values in a socially acceptable, non-offensive, and non-destructive manner.

Independence is the ability to be self directed and free from emotional dependency on others. Decision-making, planning, and daily tasks are completed autonomously.

DECISION MAKING

Problem Solving is the ability to find solutions to problems in situations where emotions are involved. Problem solving includes the ability to understand how emotions impact decision making.

Reality Testing is the capacity to remain objective by seeing things as they really are. This capacity involves recognizing when emotions or personal bias can cause one to be less objective.

Impulse Control is the ability to resist or delay an impulse, drive or temptation to act and involves avoiding rash behaviors and decision making.

INTERPERSONAL

Interpersonal Relationships refers to the skill of developing and maintaining mutually satisfying relationships that are characterized by trust and compassion.

Empathy is recognizing, understanding, and appreciating how other people feel. Empathy involves being able to articulate your understanding of another's perspective and behaving in a way that respects others' feelings.

Social Responsibility is willingly contributing to society, to one's social groups, and generally to the welfare of others. Social Responsibility involves acting responsibly, having social consciousness, and showing concern for the greater community.

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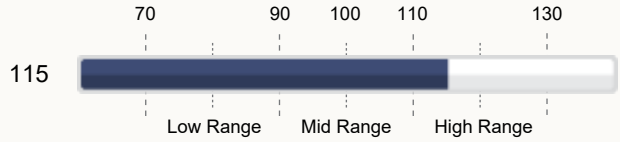
Overview

Total EI



Self-Perception Composite

118

Self-Regard
Respecting oneself; Confidence

106

Self-Actualization
Pursuit of meaning; Self-improvement

117

Emotional Self-Awareness
Understanding own emotions

125

Self-Expression Composite

104

Emotional Expression
Constructive expression of emotions

112

Assertiveness
Communicating feelings, beliefs; Non-offensive

85

Independence
Self-directed; Free from emotional dependency

106

Interpersonal Composite

120

Interpersonal Relationships
Mutually satisfying relationships

123

Empathy
Understanding, appreciating how others feel

110

Social Responsibility
Social conciousness; Helpful

118

Decision Making Composite

118

Problem Solving
Find solutions when emotions are involved

114

Reality Testing
Objective; See things as they really are

110

Impulse Control
Resist or delay impulse to act

117

Stress Management Composite

103

Flexibility
Adapting emotions, thoughts and behaviors

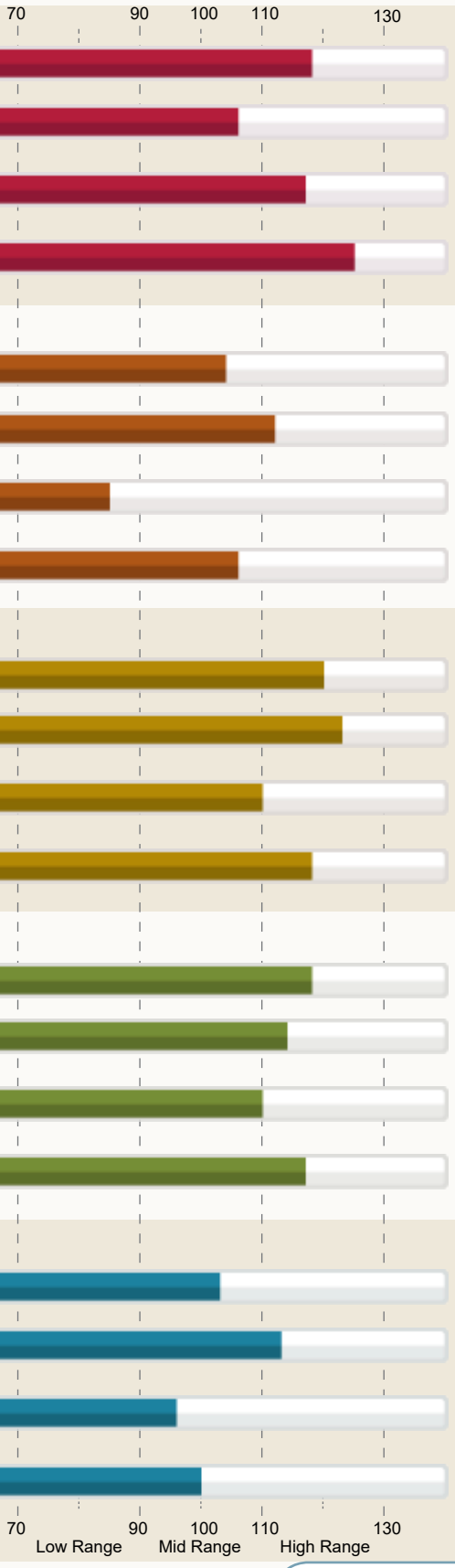
113

Stress Tolerance
Coping with stressful situations

96

Optimism
Positive attitude and outlook on life

100



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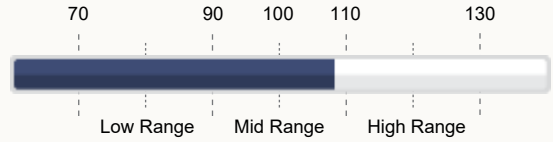
Overview

Total EI

108



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Social conciousness; Helpful

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Find solutions when emotions are involved

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Objective; See things as they really are

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Resist or delay impulse to act

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Flexibility
Adapting emotions, thoughts and behaviors

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Stress Tolerance
Coping with stressful situations

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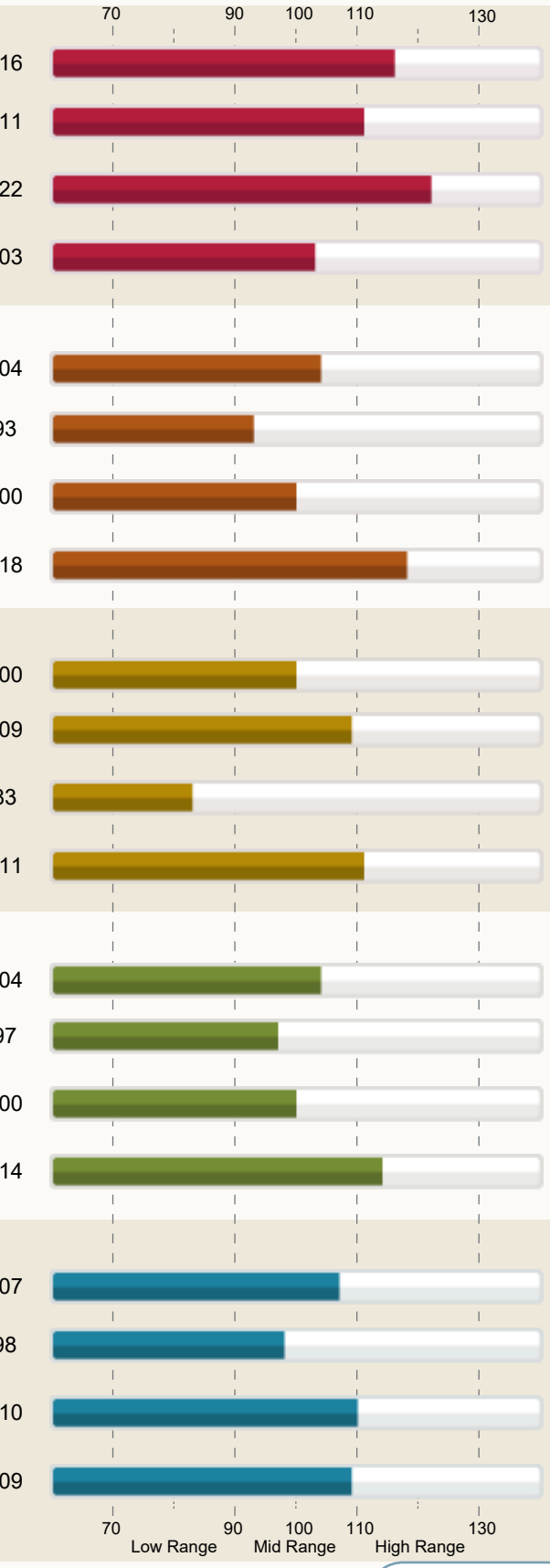
Optimism
Positive attitude and outlook on life

109



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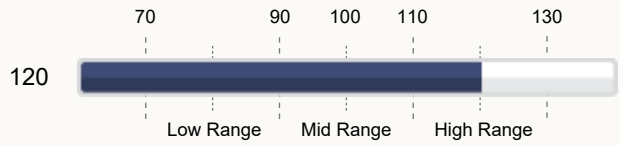

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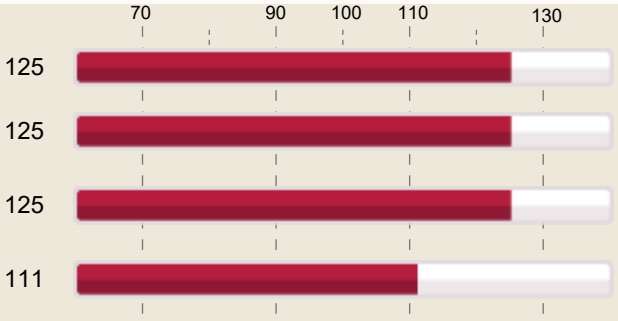

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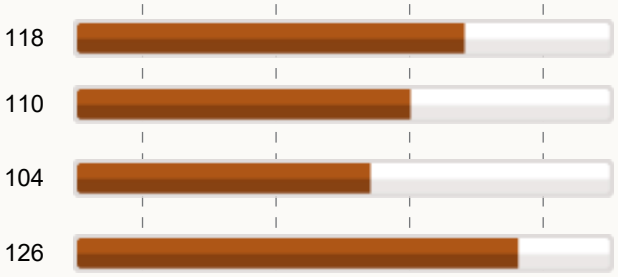
Respecting oneself; Confidence

Self-Actualization
Pursuit of meaning; Self-improvement

Emotional Self-Awareness
Understanding own emotions

Self-Expression Composite

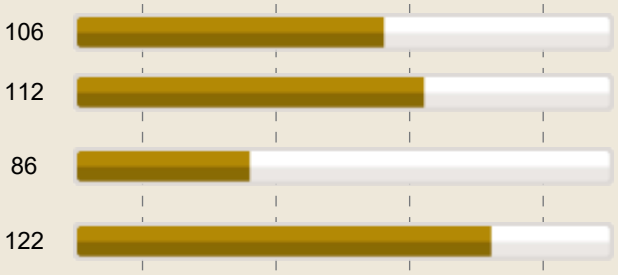


Emotional Expression
Constructive expression of emotions

Assertiveness
Communicating feelings, beliefs; Non-offensive

Independence
Self-directed; Free from emotional dependency

Interpersonal Composite

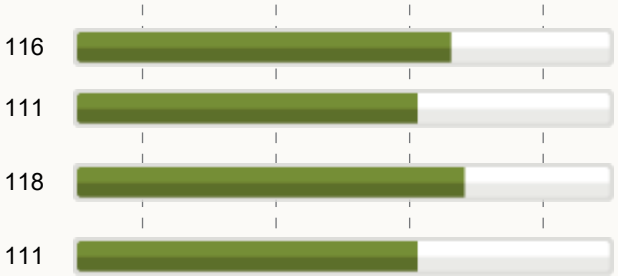


Interpersonal Relationships
Mutually satisfying relationships

Empathy
Understanding, appreciating how others feel

Social Responsibility
Social conciousness; Helpful

Decision Making Composite

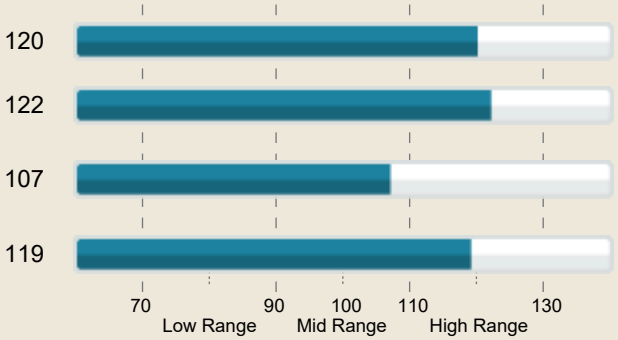


Problem Solving
Find solutions when emotions are involved

Reality Testing
Objective; See things as they really are

Impulse Control
Resist or delay impulse to act

Stress Management Composite



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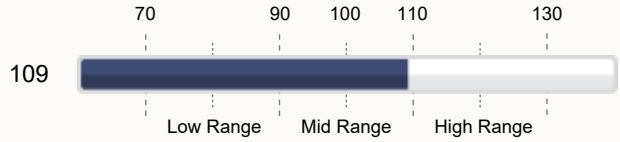

Self-Perception Composite

92

Self-Regard
Respecting oneself; Confidence

92

Self-Actualization
Pursuit of meaning; Self-improvement

102

Emotional Self-Awareness
Understanding own emotions

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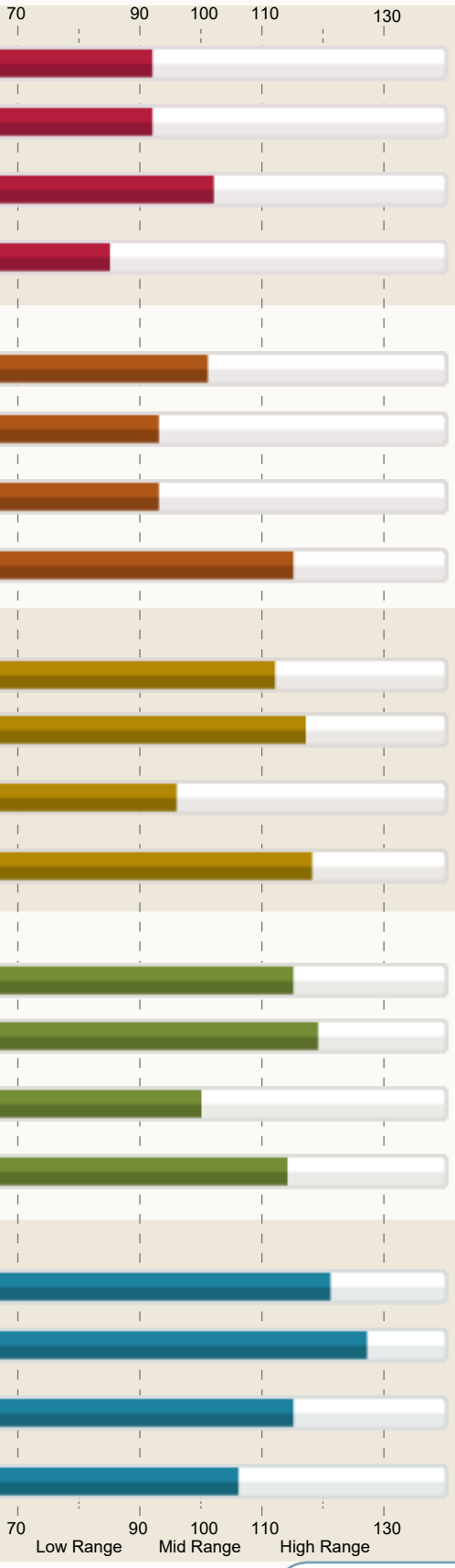

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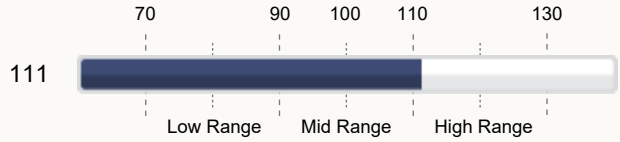

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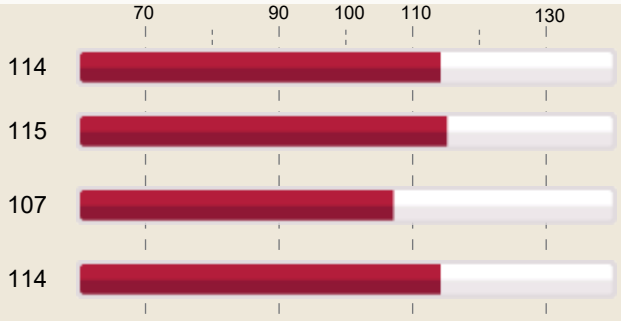

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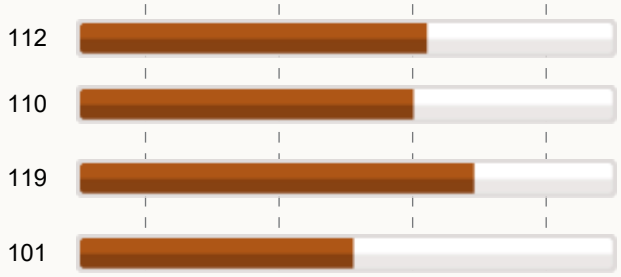

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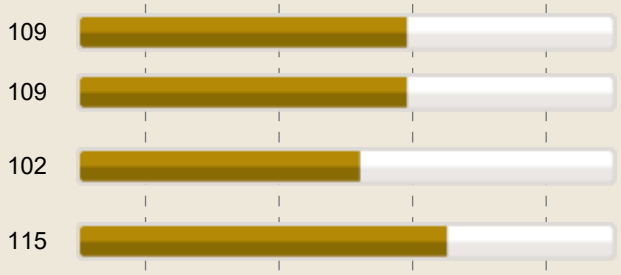

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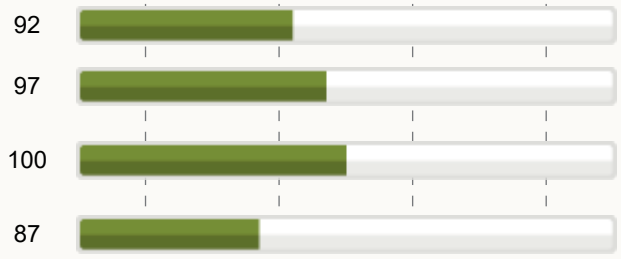

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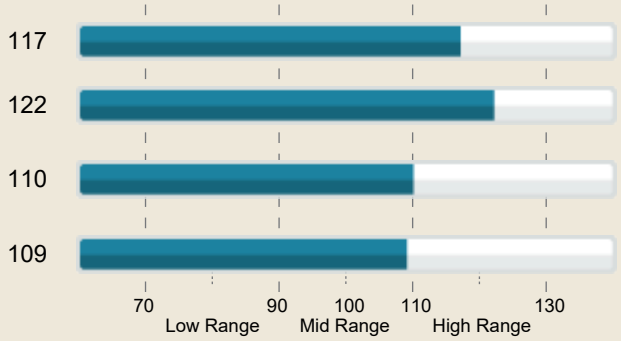

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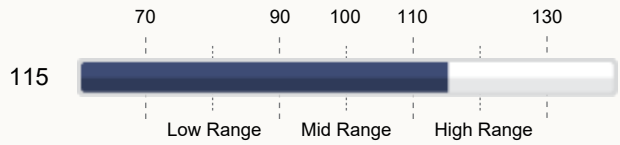
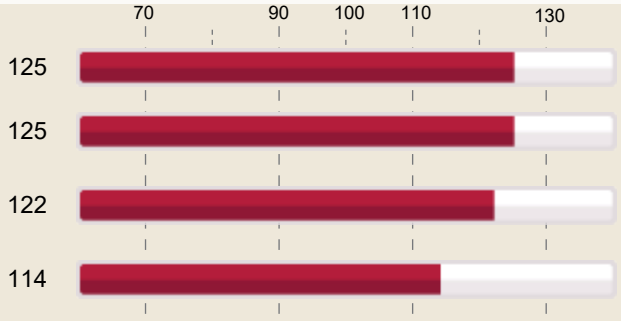


Self-Perception Composite



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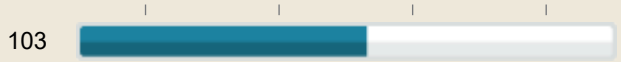

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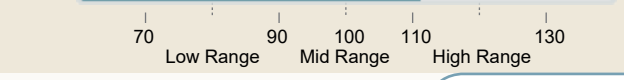

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EQ-i 2.0

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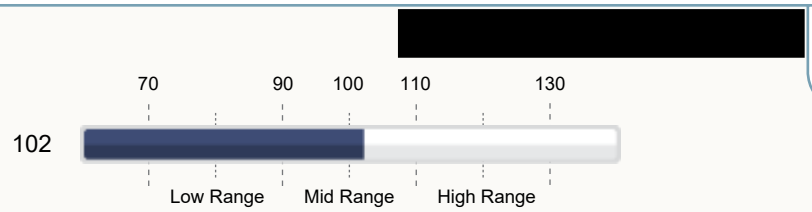

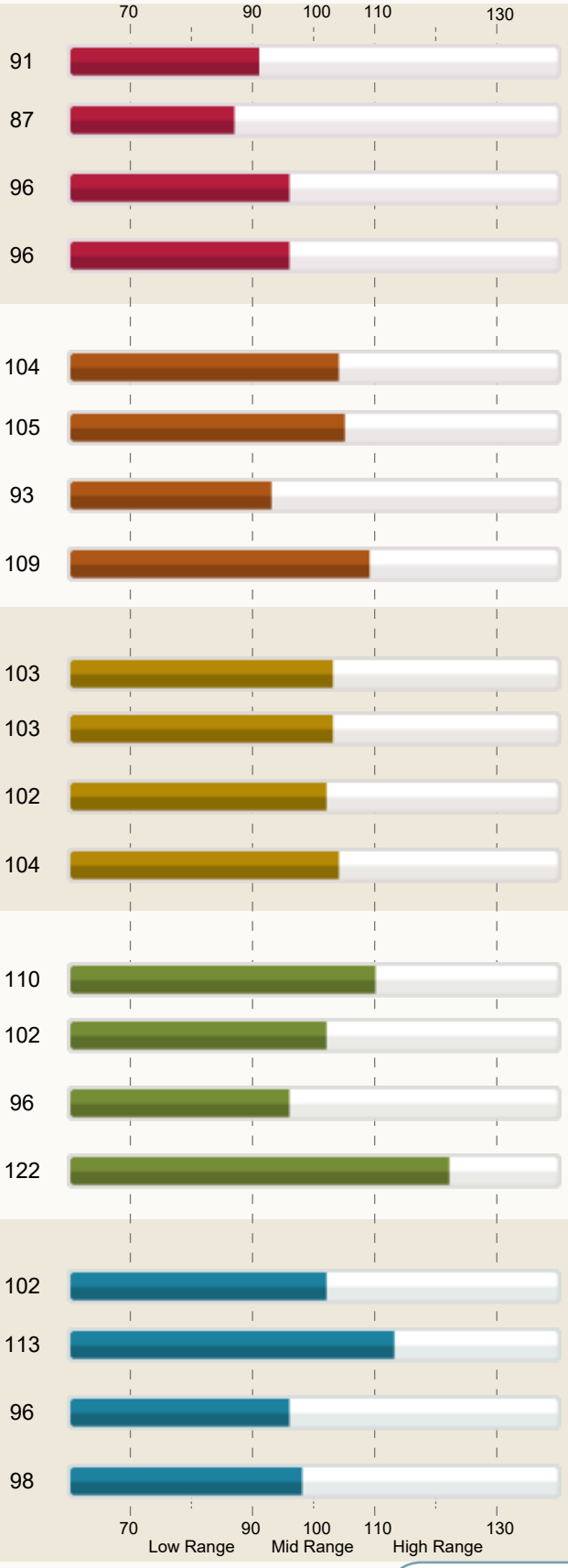

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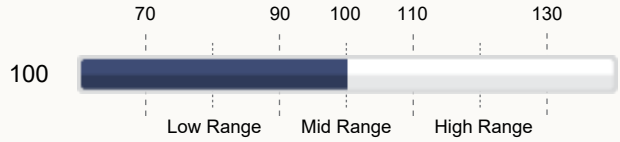

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Self-Actualization
Pursuit of meaning; Self-improvement

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Emotional Self-Awareness
Understanding own emotions

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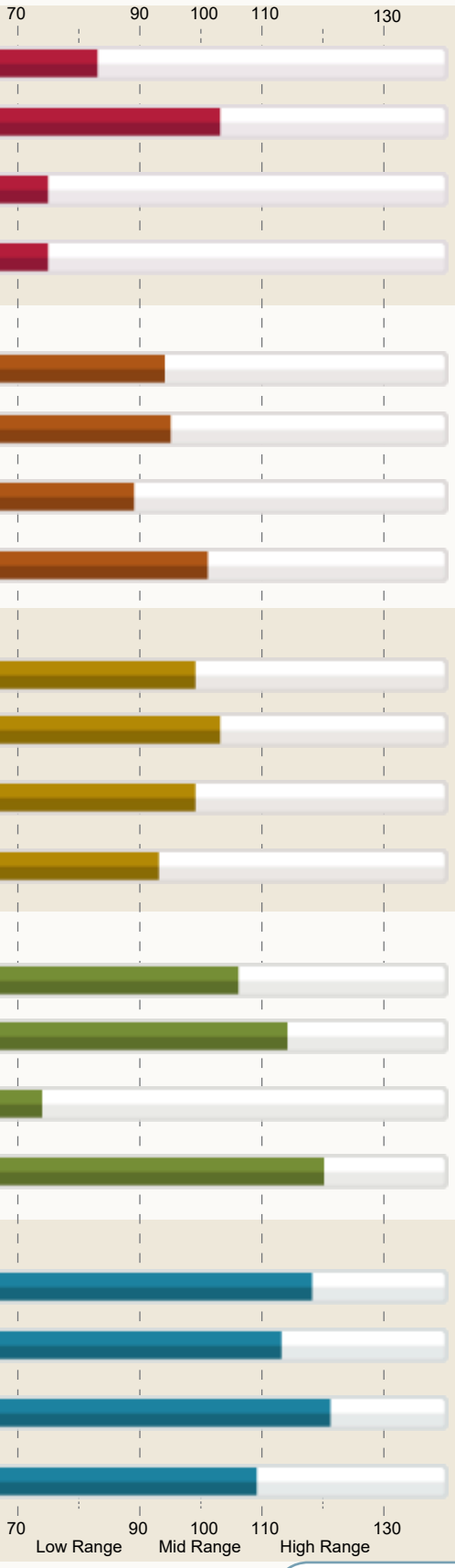

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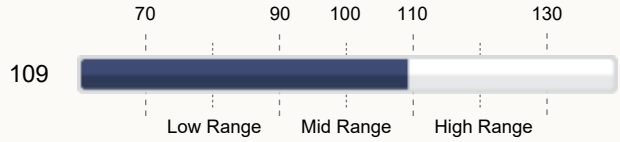
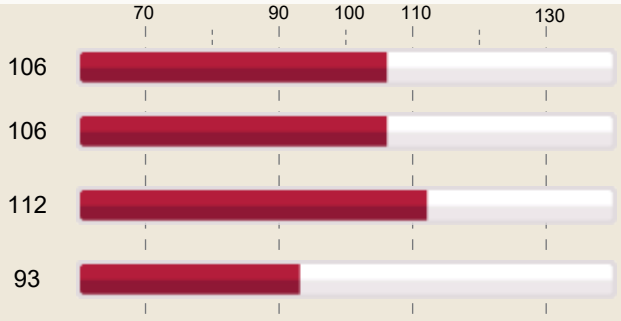


Self-Perception Composite

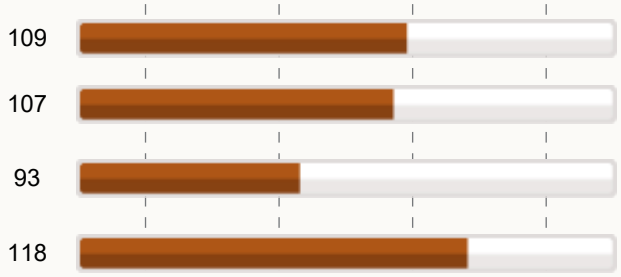


Self-Regard
Respecting oneself; Confidence

Self-Actualization
Pursuit of meaning; Self-improvement

Emotional Self-Awareness
Understanding own emotions

Self-Expression Composite

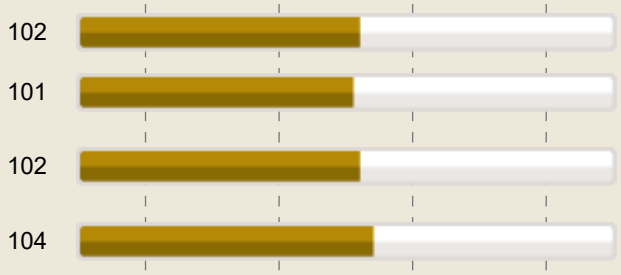


Emotional Expression
Constructive expression of emotions

Assertiveness
Communicating feelings, beliefs; Non-offensive

Independence
Self-directed; Free from emotional dependency

Interpersonal Composite

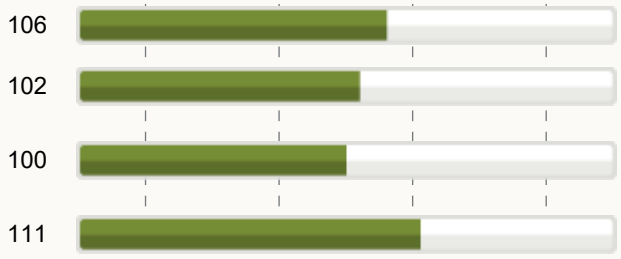


Interpersonal Relationships
Mutually satisfying relationships

Empathy
Understanding, appreciating how others feel

Social Responsibility
Social conciousness; Helpful

Decision Making Composite

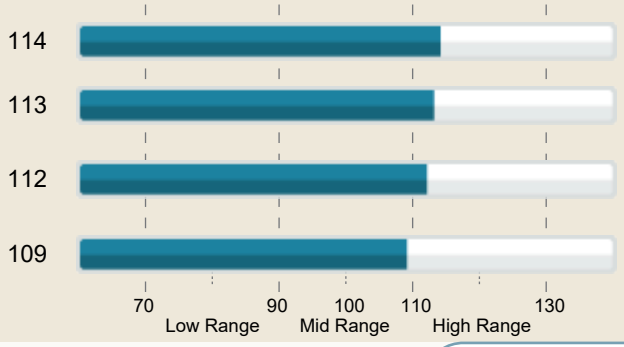


Problem Solving
Find solutions when emotions are involved

Reality Testing
Objective; See things as they really are

Impulse Control
Resist or delay impulse to act

Stress Management Composite



Flexibility
Adapting emotions, thoughts and behaviors

Stress Tolerance
Coping with stressful situations

Optimism
Positive attitude and outlook on life

4994-95A3-7A61

EQ-i 2.0
assess. predict. perform.

My EI Report

Student Comprehensive

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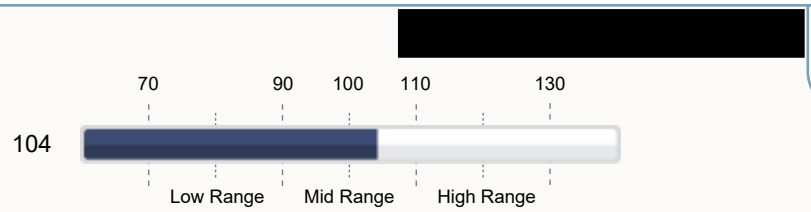

Self-Perception Composite

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Self-Regard
Respecting oneself; Confidence

101

Self-Actualization
Pursuit of meaning; Self-improvement

102

Emotional Self-Awareness
Understanding own emotions

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Self-Expression Composite

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Emotional Expression
Constructive expression of emotions

112

Assertiveness
Communicating feelings, beliefs; Non-offensive

104

Independence
Self-directed; Free from emotional dependency

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Interpersonal Composite

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Interpersonal Relationships
Mutually satisfying relationships

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Empathy
Understanding, appreciating how others feel

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Social Responsibility
Social conciousness; Helpful

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Decision Making Composite

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Problem Solving
Find solutions when emotions are involved

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Reality Testing
Objective; See things as they really are

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Impulse Control
Resist or delay impulse to act

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Stress Management Composite

100

Flexibility
Adapting emotions, thoughts and behaviors

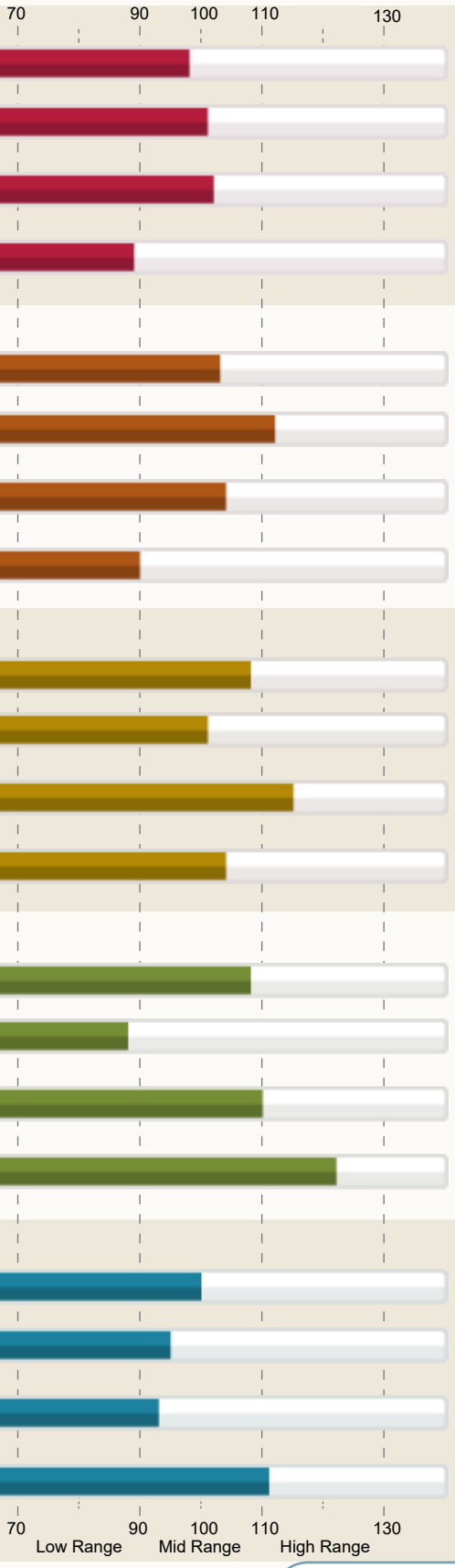
95

Stress Tolerance
Coping with stressful situations

93

Optimism
Positive attitude and outlook on life

111



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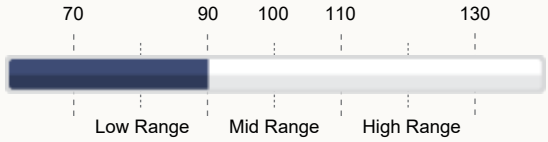

EQ-i 2.0

Self-Perception Composite

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Self-Regard
Respecting oneself; Confidence

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Self-Actualization
Pursuit of meaning; Self-improvement

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Emotional Self-Awareness
Understanding own emotions

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Self-Expression Composite

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Emotional Expression
Constructive expression of emotions

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Assertiveness
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Independence
Self-directed; Free from emotional dependency

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Interpersonal Composite

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Interpersonal Relationships
Mutually satisfying relationships

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Empathy
Understanding, appreciating how others feel

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Social Responsibility
Social conciousness; Helpful

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Decision Making Composite

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Problem Solving
Find solutions when emotions are involved

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Reality Testing
Objective; See things as they really are

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Impulse Control
Resist or delay impulse to act

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Stress Management Composite

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Flexibility
Adapting emotions, thoughts and behaviors

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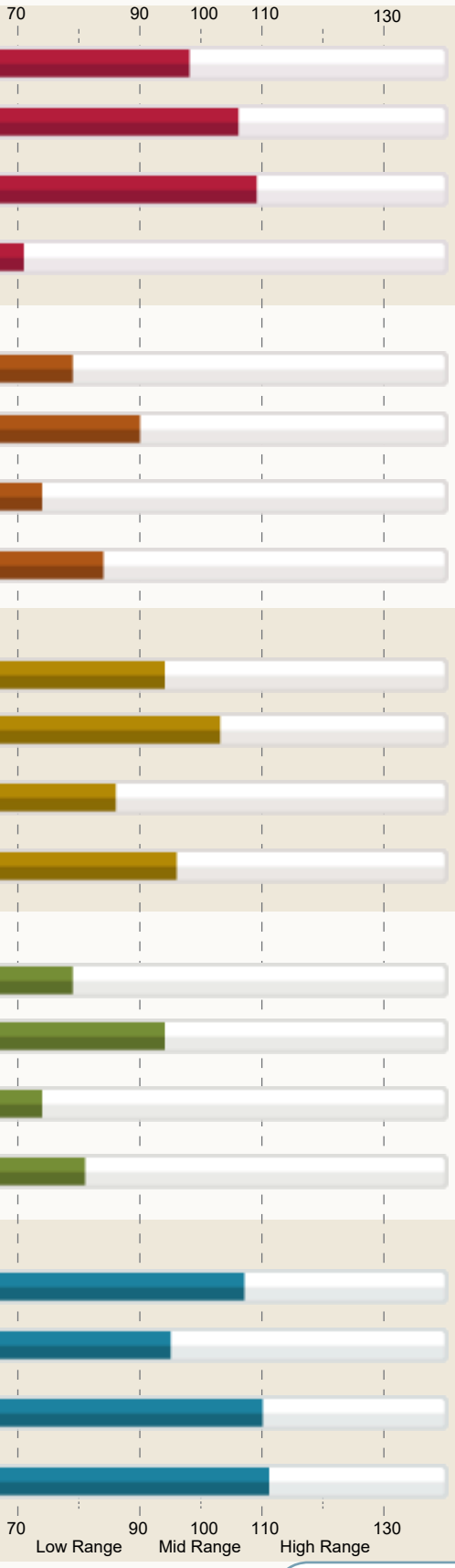
Stress Tolerance
Coping with stressful situations

110

Optimism
Positive attitude and outlook on life

111



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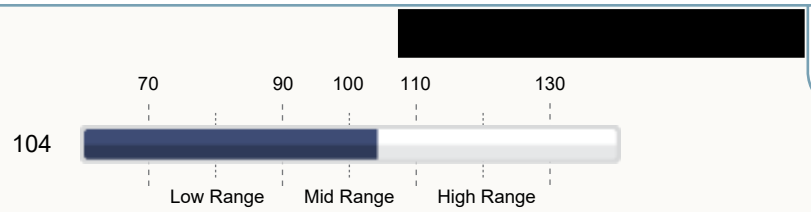

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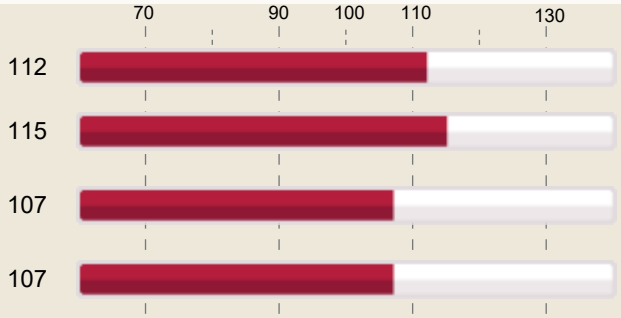

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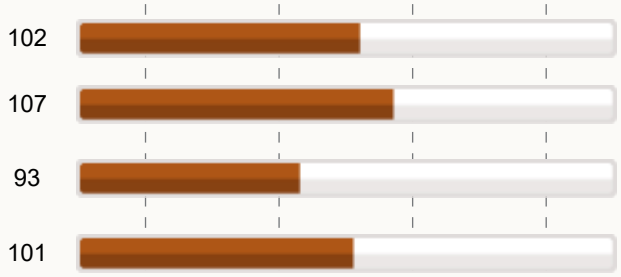

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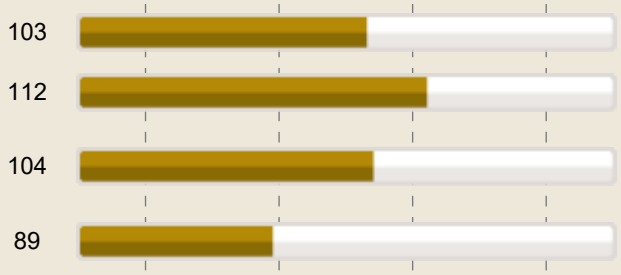
Interpersonal Composite



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Mutually satisfying relationships

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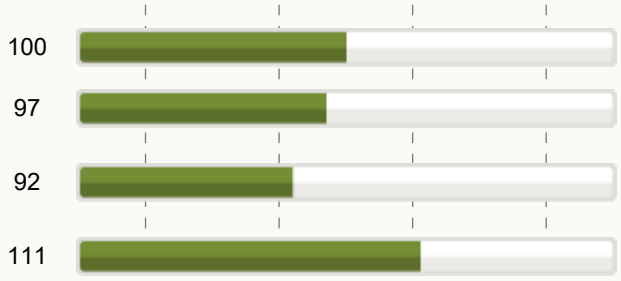
Social conciousness; Helpful

Decision Making Composite



Problem Solving
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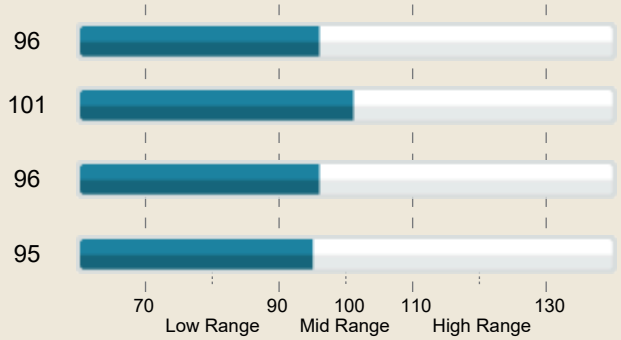
Stress Management Composite



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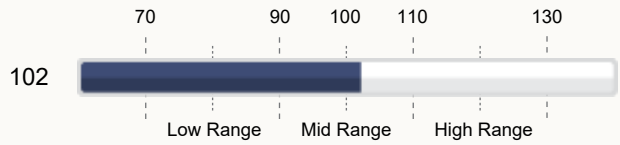

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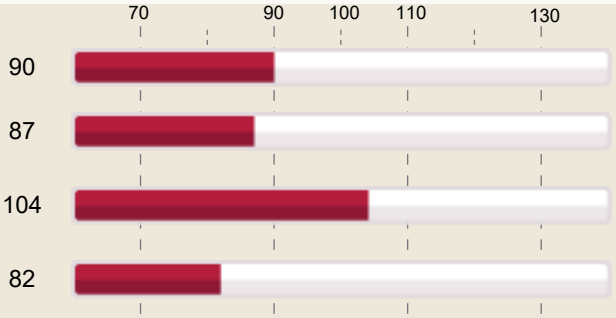

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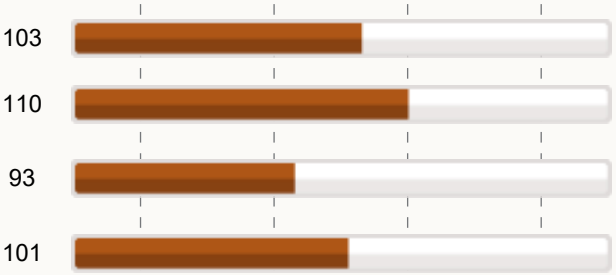
Understanding own emotions

Self-Expression Composite



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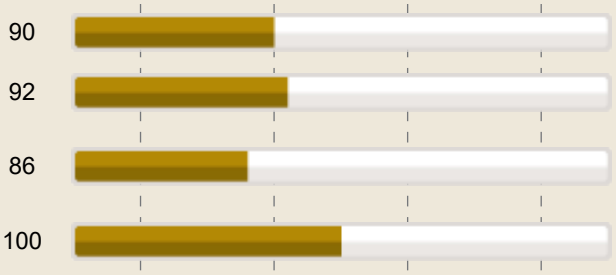

Interpersonal Relationships
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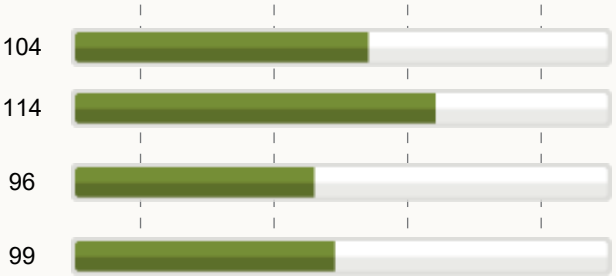
Social conciousness; Helpful

Decision Making Composite



Problem Solving
Find solutions when emotions are involved

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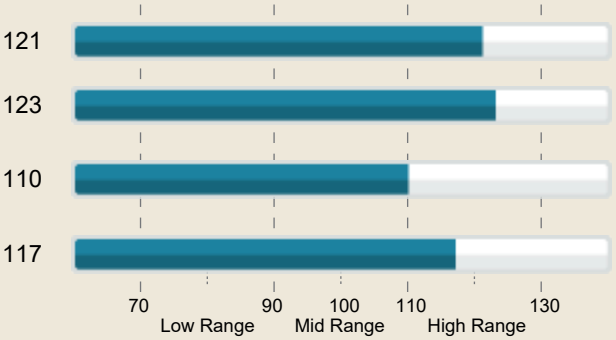
Impulse Control
Resist or delay impulse to act

Stress Management Composite



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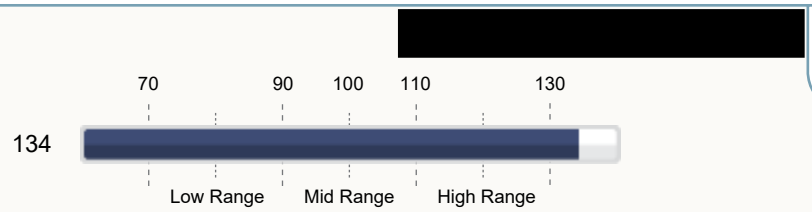

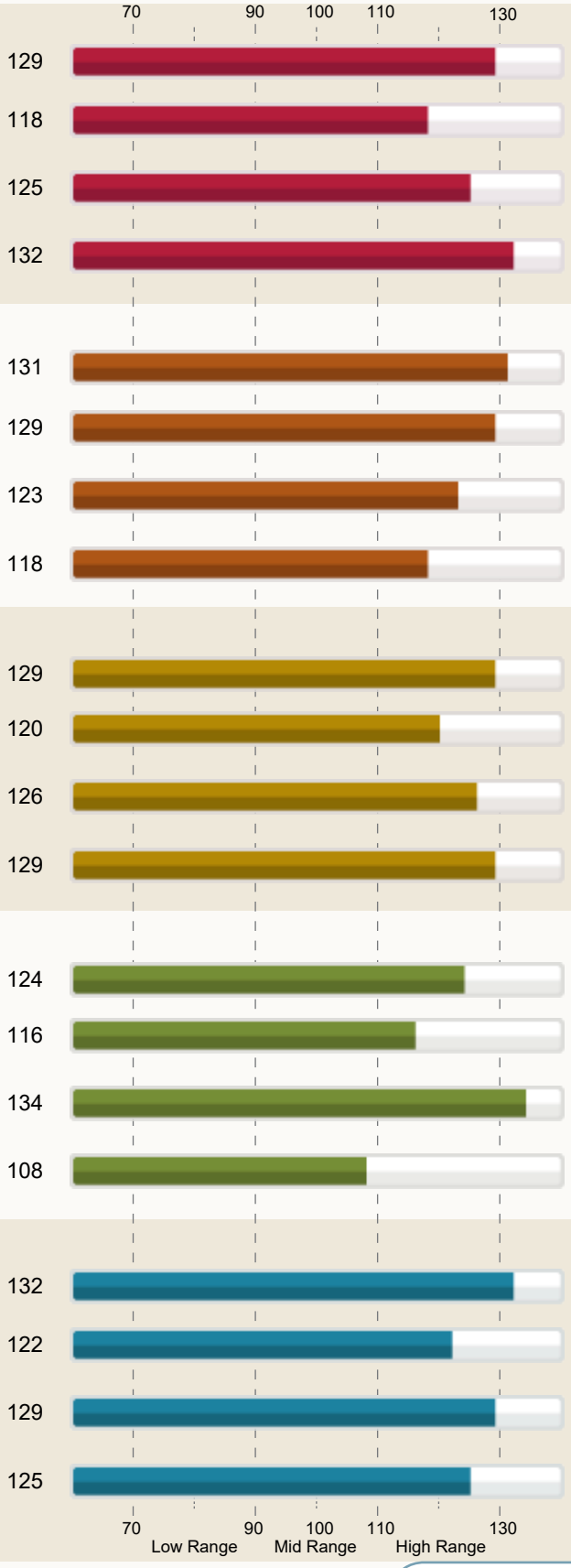

Self-Perception Composite

Self-Regard
Respecting oneself; Confidence

Self-Actualization
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Emotional Self-Awareness
Understanding own emotions

Self-Expression Composite

Emotional Expression
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Interpersonal Relationships
Mutually satisfying relationships

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Student Comprehensive

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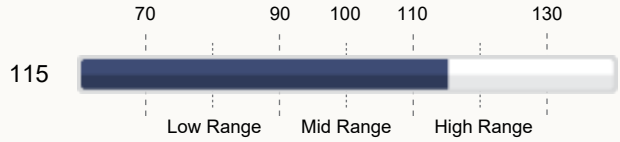

Self-Perception Composite

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Self-Regard
Respecting oneself; Confidence

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Self-Actualization
Pursuit of meaning; Self-improvement

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Emotional Self-Awareness
Understanding own emotions

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Self-Expression Composite

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Interpersonal Relationships
Mutually satisfying relationships

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Find solutions when emotions are involved

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Stress Management Composite

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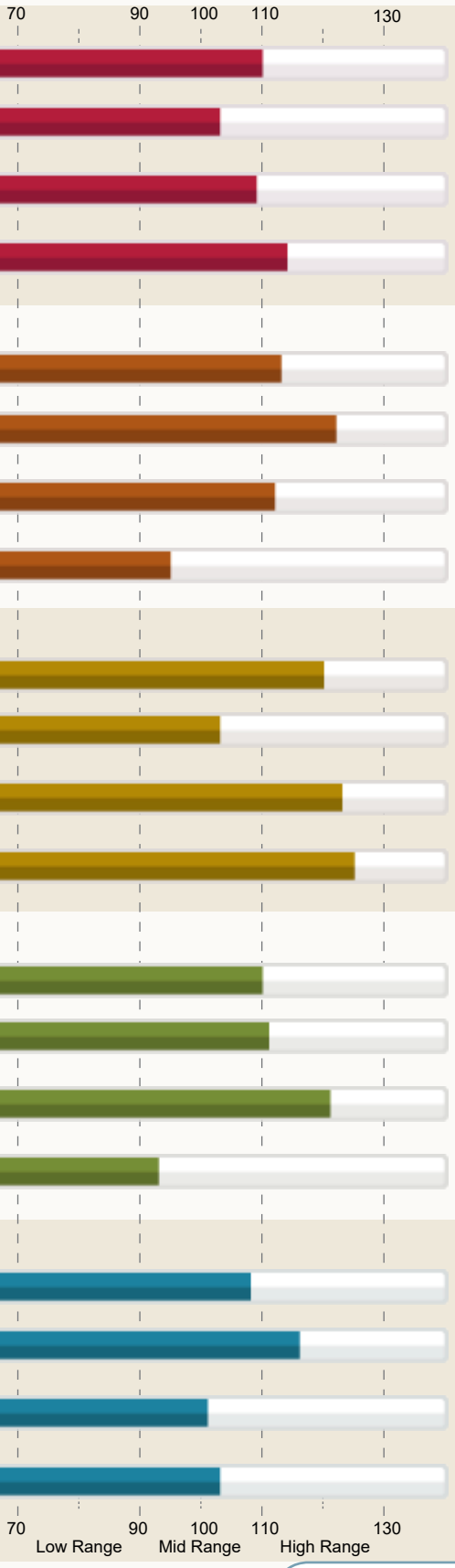

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Overview

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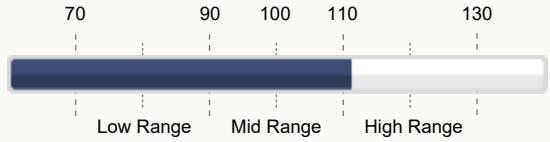

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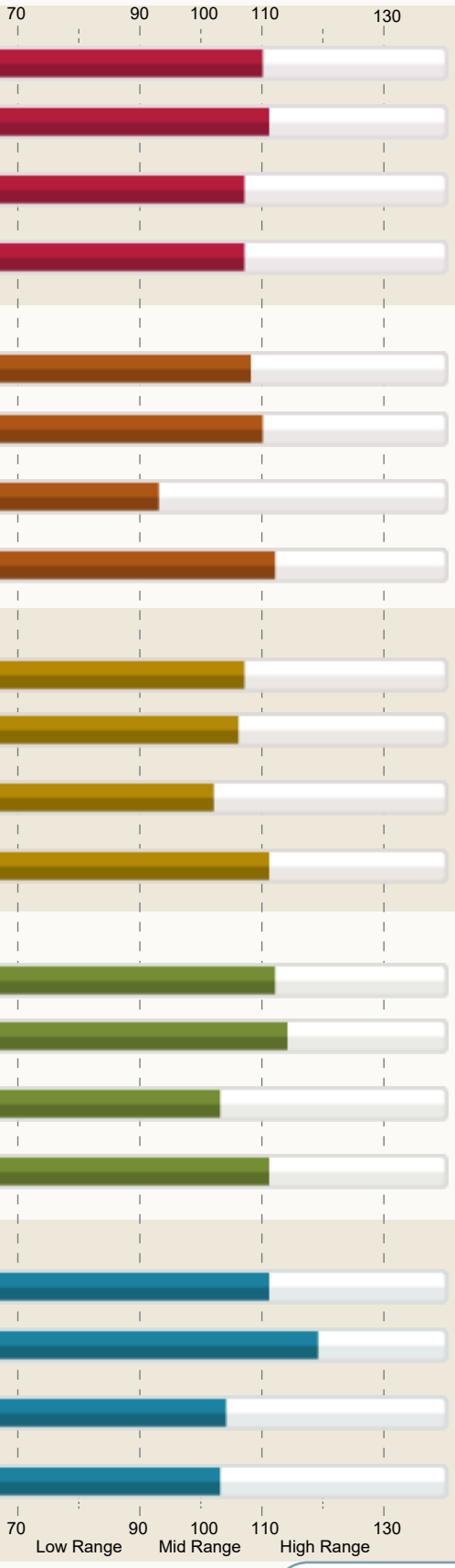

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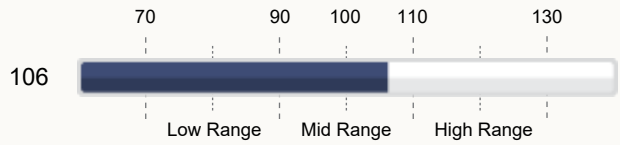

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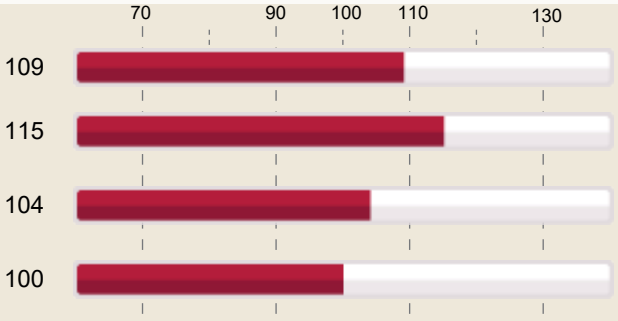

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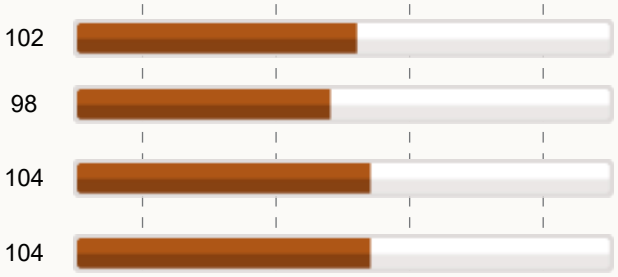

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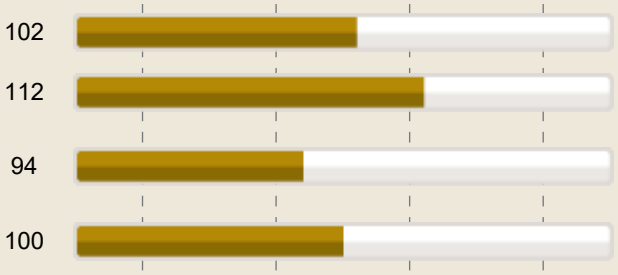

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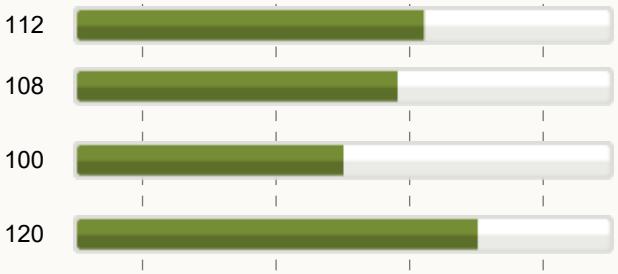

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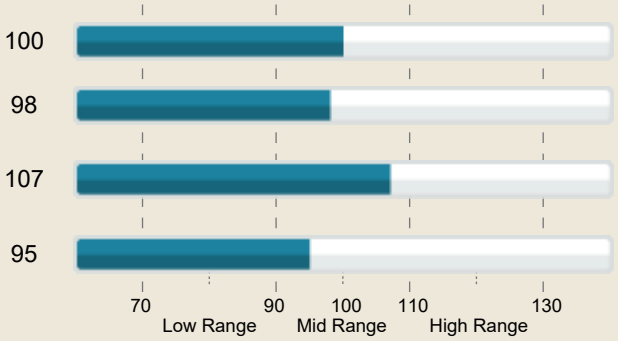

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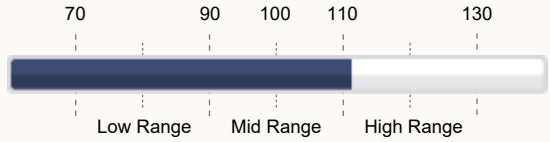
Total EI

111



Self-Perception Composite

95

Self-Regard
Respecting oneself; Confidence

101

Self-Actualization
Pursuit of meaning; Self-improvement

99

Emotional Self-Awareness
Understanding own emotions

85

Self-Expression Composite

123

Emotional Expression
Constructive expression of emotions

124

Assertiveness
Communicating feelings, beliefs; Non-offensive

108

Independence
Self-directed; Free from emotional dependency

118

Interpersonal Composite

106

Interpersonal Relationships
Mutually satisfying relationships

106

Empathy
Understanding, appreciating how others feel

104

Social Responsibility
Social conciousness; Helpful

104

Decision Making Composite

111

Problem Solving
Find solutions when emotions are involved

119

Reality Testing
Objective; See things as they really are

96

Impulse Control
Resist or delay impulse to act

108

Stress Management Composite

113

Flexibility
Adapting emotions, thoughts and behaviors

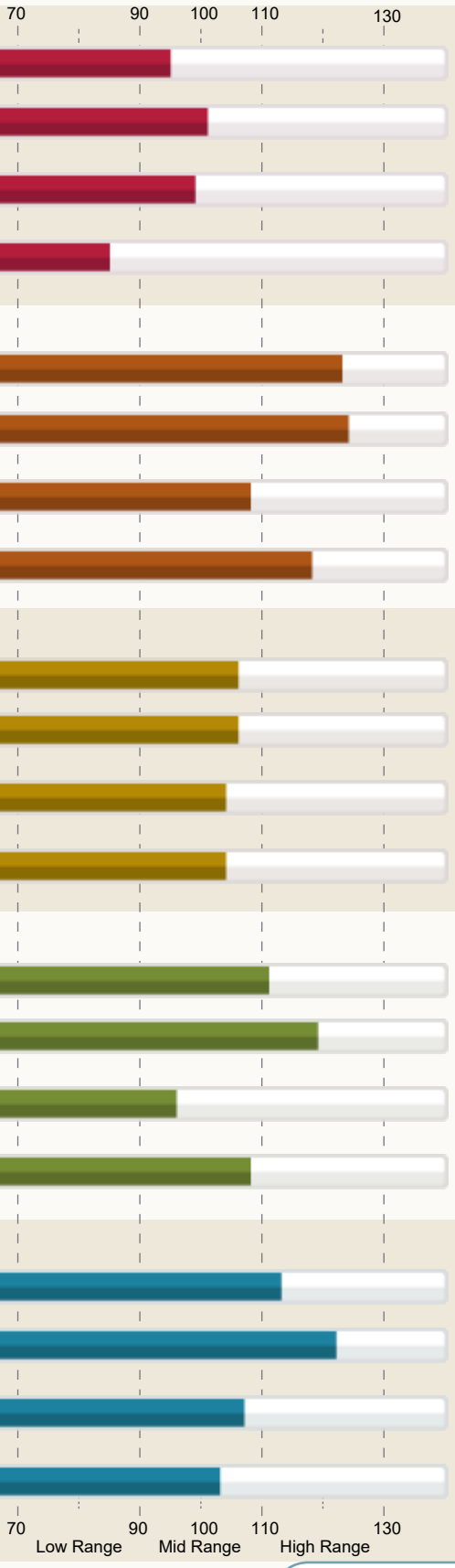
122

Stress Tolerance
Coping with stressful situations

107

Optimism
Positive attitude and outlook on life

103



4994-95A3-7A61

Appendix C: Course Design Documents

Course Context

Department of Civil Engineering

Indigenous Infrastructure

CIVE 412 *Redesign*

Location XXXX

Spring Term 2022

Course Background

a. The *specific* context of the course:

Question	Answer
Pre-requisites	None, although "Engineering and Technology" – ENGR297 would be a benefit
Number of students	32 (to make 8 project groups of 4)
Course level	4th year level
Class requirements	1 – Three-hour block per week
Course delivery	In classroom if COVID-19 restrictions permit. An online option can be easily implemented using Zoom and a participatory design platform like Miro or Mural. I will use a flipped classroom approach where students can learn asynchronously and come to class prepared to discuss the lesson material and participate in activities.

b. The *general* context of the course:

Question	Answer
Does the course need to adhere to any learning outcomes/competencies related to the university, the profession, or society as a whole?	There are learning competencies for engineers given by the Canadian Engineering Accreditation Board. This course will support the following graduate attributes in the following ways: **Investigation**: Students will conduct investigations of issues facing Indigenous communities and gather qualitative and quantitative data that will help them appropriately frame a design problem and create logical solutions to infrastructure related community issues. **Design**: Students will employ techniques of human-centered design in order to develop solutions that meet specified needs with appropriate attention to health and safety risks, applicable standards, and economic, environmental, cultural and societal considerations for "wicked" problems facing Indigenous communities. **Individual and team work**: Students will work in a collaborative environment, developing a "whole systems" solution to a "wicked

	problem" facing a partner community, or Network of Indigenous Communities. **Professionalism**: Students will reflect on their as roll as an engineer in society, and the motivations that led them to enter engineer school, through an emphasis on self-reflection and formative feedback. Attention will be paid to how engineers protect public interest and their duty to society and the environment. **Impact of engineering on society and the environment**: Students will gain an appreciation for social and environmental interconnectedness and the impact of engineering activities on complex societal systems as they engage with Indigenous communities with different world-views on a real-world project. They will gain a deep understanding that uncertainties in prediction in such systems create a need for a new approach to design that centers human-considerations and environmental health and well-being. They will gain first hand experience with this complexity, and implement a type of design that is intended for engaging with wicked problems.

Nature of the Course Subject Matter

Question	Answer
What are the main concepts to be taught? Keep to as few main concepts as possible.	**Introduction to Community Based Research Techniques with Indigenous Communities** ➢ Co-design of building retrofit strategies, renewable energy projects, housing strategies, or sustainable economic development opportunities that support Indigenous Communities. ➢ Empathetic design framework (Design Thinking and Systems Thinking) ○ Iterative problem framing ○ Empathetic research techniques ○ Concept development and evaluation ○ Rapid prototyping ○ Concept implementation and Road mapping **See IDEO Field guide to human-centric design**
	Reflective Practice ➢ Identifying personal biases, limitations, and areas for personal growth. ➢ What it means to understand Other's perspectives. ➢ The importance of empathy in design ➢ Approaching design with a "Growth Mindset"
	Challenges facing Indigenous communities ➢ Barriers to infrastructure development in Indigenous Communities ➢ Introduction to Indigenous Protected and Conserved Areas

Characteristics of the *Learners*

Question	Answer
Professional profile of students in this course	The students who will be most successful in this class are students who: ➢ Want to use their degree in civil engineering to be part of interdisciplinary teams working on complex societal issues such as poverty, climate change, resource depletion, reconciliation, conservation, etc... ➢ Have a strong self-reflective practice that enables them to think critically about their feelings and actions and learn from them. ➢ Have a desire to see things from diverse perspectives. ➢ Have a desire to help, connect with, and empathize with people. ➢ Have a strong interest in innovation and design.
What prior knowledge and experience do students usually have about the subject of this course?	Students will be familiar with the engineering design method and will have a strong technical foundation. They will likely not have had experience working with Indigenous communities, or with design-thinking, systems thinking or empathetic design.
Student motivations	Students who register for this course may fall into a variety of categories. Some will feel motivated and inspired by the subject matter and will see this as an opportunity to experience how they can use their education to fulfill a desire to improve society. Others may be registering in this course as they see it as something that is different from their typical engineering courses and may expect it to be an "easy A", which will make the workload and learning curve a surprise to them.
What do you think will be the learning goals and expectations of the students?	**Learning Goals:** ➢ Learn additional tools that will help them in their career. ➢ Gain experience working on a real-world project. ➢ Build friendships and relationships with their peers. ➢ Find a subject related to their career direction that they feel motivated and inspired by. **Expectations**: ➢ To be able to exercise their creativity. ➢ To receive fair, timely, and relevant feedback on assessments. ➢ To work in teams. ➢ To gain knowledge that will help them in their careers. ➢ To put in some hours and effort outside of class time working on assigned work.
What will be familiar to the students?	Depending on the direction the students choose to go in their project (as there will be a large degree of autonomy in order to most accurately simulate a real-world design scenario), they may see familiar concepts such as infrastructure planning, building science, energy modelling, and renewable energy project planning. They will get an opportunity to use the

	engineering knowledge base that they have developed throughout their academic career in a real-world project.
What will be surprising?	Students will likely be surprised by different approach to design that will be taught through Design Thinking and Systems Thinking. They may be surprised by the concept of wicked problems and how the traditional approach to design is ineffective for these problems. They will be surprised by the focus on empathetic design strategies (such as observation and interviewing), and qualitative data analysis, and will not have experienced a decision making process based on subjective analysis. Depending on their motivations, students who are motivated to use their engineering education to forge a better future for humanity may feel that this type of design inspires them to learn more. They may also be surprised that this course will push them to grow personally as well as professionally, as it will have a heavy emphasis on developing the "whole professional", as described by David E. Goldberg in his book "A Whole New Engineer", and in the report "Educating the Engineer of 2020" by the National Academy of Engineering. This will be accomplished primarily through an emphasis on self-reflection and metacognition, which will be built into the assignments.

Pedagogical Approach

There is a growing body of research to show that engineering education, with its heavy focus on the development of technical competencies (stemming from the 1950's), is not reflective of real-world engineering practice. Engineering is an inherently social profession. If engineers are expected to play a role in addressing issues that exist and the intersection of technology and society they must have a deep understanding of both technical competencies and of human factors. They must have the ability to *empathize*. This course presents an opportunity to integrate emotional competencies into the engineering curriculum in a deliberate way in a real-world situation through the use of Design Thinking and collaborative design.

Pedagogical Approach	**Literature References**
Deliberately create an educational environment that promotes empathy	(Wong K. , et al., 2016) (Walther J. , Brewer, Sochacka, & Miller , 2019) (Bielefeldt & Canney, 2015) (Strobel, Hess, Pan, & Wachter Morris, 2013) (Brewer, Sochacka, Walther, & Miller, 2017)
Explicitly address empathy and its place in engineering	(Walther J. , Brewer, Sochacka, & Miller , 2019) (Strobel, Hess, Pan, & Wachter Morris, 2013)
Bring in additional faculty when discussing empathy to highlight its importance.	(Wong K. , et al., 2016)
Attend to student's professional identity formation and conceptions of what it means to be an engineer	(Carroll, Wang, & Delaine, 2018) (Fila , et al., 2014) (Walther, Miller, & Sochacka, 2017) (Walther J. , Brewer,

• Encourage self-reflection • Encourage professional socialization with engineering practitioners • Encourage students to grapple with what it means to be an engineer.	Sochacka, & Miller , 2019) (Cech, 2014) (Bielefeldt & Canney, 2015)
Incorporate real world experiences based on community engagement, service learning, and design thinking	(Woodock, McDonagh, Magee, Ball, & Iqbal, 2019) (Carroll, Wang, & Delaine, 2018) (Strobel, Hess, Pan, & Wachter Morris, 2013) (Walther, Miller, & Sochacka, 2017) (Fila , et al., 2014) (Rasoal, Danielsson, & Jungert, 2012) (Wong K. , et al., 2016) (Bairaktarova, Bernstein, Reid, & Ramani, 2016) (Hoople & Choi-Fitzpatrick, 2017) (Bielefeldt & Canney, 2015) (Canney & Bielefeldt, 2015)
Encourage Teamwork and interdisciplinary engagement	(Hoople & Choi-Fitzpatrick, 2017) (Fila , et al., 2014) (Wong K. , et al., 2016) (Canney & Bielefeldt, 2015) (Fila , et al., 2014) (Walther, Miller, & Kellam, 2012) (Hoople & Choi-Fitzpatrick, 2017)

[redacted]

DEAR NATION LEADERSHIP

DO YOU HAVE A SMALL INFRASTRUCTURE RELATED DESIGN CHALLENGE?

We are looking for community based projects where 4th year civil engineering students can engage with Nation staff and partners in the co-design of solutions to small infrastructure related design challenges. The University of Victoria has been intertwining Indigenous topics into some of the engineering curriculum. Specifically, CIVE 412: Infrastructure Engineering in Indigenous Communities is a fourth-year engineering course focused providing fourth year civil engineering students with an introduction to working with Indigenous communities and exposing them to the systems these communities operate in, best practices of working with Indigenous peoples and communities, empathetic design and how it relates to working in engineering, and community based projects. The students participate in cultural training that helps align them with the course material and prepares them for working with Indigenous partners. They are introduced to an "Ethical Space" framework designed to create a place for Indigenous and Western knowledge systems to interact with mutual respect, kindness, generosity and other basic values and principles. Eric Wilson and I will be co-teaching this course between January 2022 and April 2022.

If you have such a project, **please let us know by November 30th, 2021**. We would love to work with you to develop a scope for these projects and see how we can provide something of value for you and the students.

At the end of **January 2022**, we will be hosting a **project kick-off ceremony** for the partner Nations, students, and the student's industry mentors. This will help us start this engagement in a good way with a shared meal and the building of relationships.

Please let me know if you have any questions or want to explore opportunities to work with these soon-to-be civil engineers. We can be reached at our contacts below:

[redacted]

[redacted]

I look forward to hearing from you. Thank you for your time,

[redacted]

[redacted]

CIVE 412 - INFRASTRUCTURE ENGINEERING IN INDIGENOUS COMMUNITIES

LEARNING JOURNAL AND REFLECTIVE PAPERS

"We don't learn by experience... we learn by reflecting on experience"
John Dewey

INTRODUCTION

In order to help you develop your self-reflective practice, you will be doing a lot of self-reflection in this course. There are three main categories of reflective assignments: 1) the "Low-stakes" Weekly Learning Journal 2) the mid-term reflection and 3) the Final Reflection. ***See the syllabus for more detail.*** Submit electronically via Brightspace. .

INTENDED LEARNING OUTCOMES

Through your active participation, you will:

- Develop yourself as a "whole professional" equipped with the tools necessary to address complex design challenges at the intersection of technology and society.
- Develop a self-reflective design mindset that will allow you to appreciate diverse perspectives and world-views to produce culturally appropriate engineering designs.
- Build your capacity to recognize and mitigate your biases and pre-conceptions, leading to better designs based on empathy and user perspectives.
- Develop a deeper understanding of the historical and present day consequences of government policy on Indigenous peoples in Canada.

DELIVERABLES

"Low-stakes" Weekly Learning Journal
Four, 500-word (approx) due:
January 26, February 2, February 9, February 16
"Low Stakes" means that they don't need to be polished papers. I am more interested in your thoughts than your ability to spell. I am going to assume that if you've made it this far, you can string a coherent sentence together if you really wanted to.

Consider your Learning Journal an opportunity to gather your thoughts for the mid-term and end-of-term reflective papers.

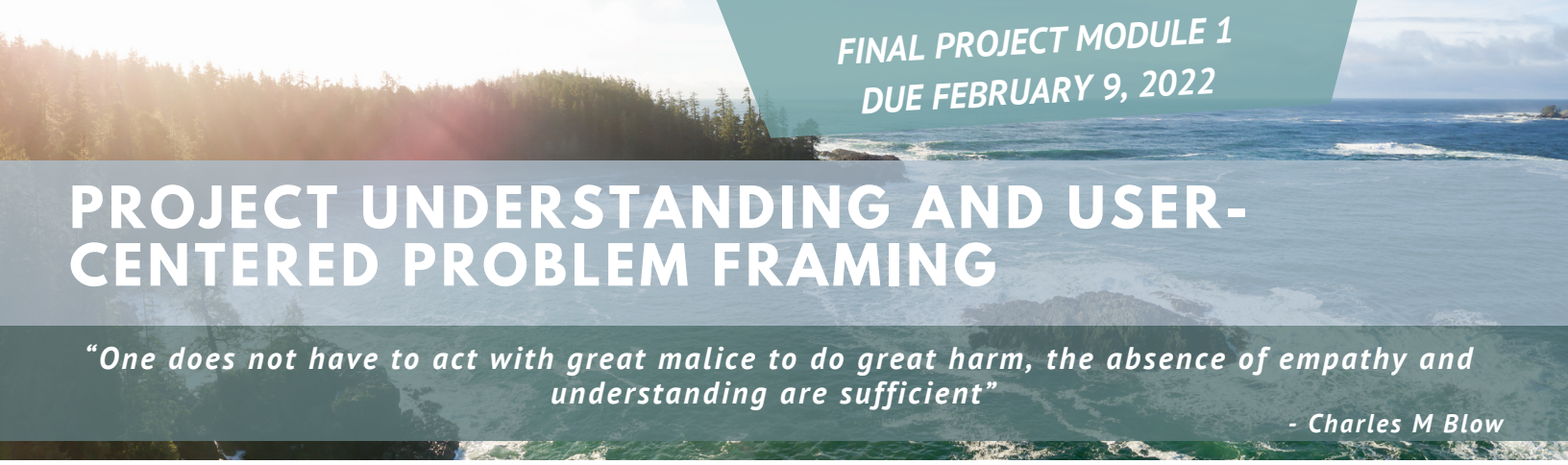
Mid-term Reflection
One, 2500-word (approx) "high-stakes" paper.

In this paper you will discuss how you are progressing in your ***Leadership Development Strategy*** and comment on your learning journey in the course to date. How did you achieve your goals? What course experiences thus far have impacted you? How will you abstract the knowledge you gained from this course to other areas of your life? **Your Learning Journal will be a good place to look for highlights and lowlights to discuss in your paper.**

Final Reflection
One 2500 word (approx) high-stakes report.

This paper will include a second EQi2.0 Assessment. You will discuss how your Emotional Intelligence shifted throughout the semester and why you think this happened. What experiences do you think produced the biggest shifts? As in the mid-term report you can discuss where you've achieved or fallen short of the goals in your Leadership Development Plan and why. You should see this as an opportunity to tell the story of your development throughout the semester.

Levels	Criteria
Reflective Practitioner **(A, A+)**	***Clarity:*** The language is clear and expressive. The reader can create a mental picture of the situation being described. Abstract concepts are explained accurately. Explanation of concepts makes sense to an uninformed reader. ***Relevance:*** The learning experience being reflected upon is relevant and meaningful to student and course learning goals. ***Analysis:*** The reflection moves beyond simple description of the experience to an analysis of how the experience contributed to student understanding of self, others, and/or course concepts. ***Interconnections:*** The reflection demonstrates connections between the experience and material from other courses; past experience; and/or personal goals. ***Self-criticism:*** The reflection demonstrates ability of the student to question their own biases, stereotypes, preconceptions, and/or assumptions and define new modes of thinking as a result.
Aware Practitioner **(B+, A-)**	***Clarity:*** Minor, infrequent lapses in clarity of expression and accuracy of the concepts being explained. ***Relevance:*** The learning experience being reflected upon is relevant and meaningful to student and course learning goals. ***Analysis:*** The reflection demonstrates an appropriate analysis of the experience, moving beyond simple description of events, but does not dive deep enough to clearly articulate how the experience contributed a deeper understanding of self, others or course concepts. ***Interconnections:*** The reflection demonstrates connections between the experience and material from other courses; past experience; and/or personal goals. ***Self-criticism:*** The reflection demonstrates ability of the student to question their own biases, stereotypes, preconceptions.
Reflection Novice **(B)**	***Clarity:*** There are frequent lapses in clarity and accuracy. ***Relevance:*** Student makes attempts to demonstrate relevance, but the relevance is unclear to the reader and does makes a limited connection to the course learning goals. ***Analysis:*** Student makes attempts at applying the learning experience to understanding of self, others, and/or course concepts but remains primarily a description of events. The analysis does not clearly articulate how the experiences led to a deeper understanding of self, others, or the course concepts. ***Interconnections:*** There is a limited demonstration of connections between the learning experiences and previous other personal and/or learning experiences. ***Self-criticism:*** There is some attempt at self-criticism, but the self-reflection does not demonstrate a new awareness of personal biases, etc.
Ample room for future improvement	***Clarity:*** Language is unclear and confusing throughout. Concepts are either not discussed or are presented inaccurately. ***Relevance:*** Most of the reflection des not connect to the student's learning goals and/or course learning goals. ***Analysis:*** Reflection does not move beyond description of the learning experience(s).



FINAL PROJECT MODULE 1
DUE FEBRUARY 9, 2022

PROJECT UNDERSTANDING AND USER-CENTERED PROBLEM FRAMING

"One does not have to act with great malice to do great harm, the absence of empathy and understanding are sufficient"

- Charles M Blow

MODULE DESCRIPTION

You will draw on the empathy building experiences in the course (such as the KAIROS exercise, the Project Kick-off Ceremony, and the community tours), and interactions with the Nation representative working with your group to formulate a short (3-page) project brief. This brief should provide background information about the Nation, discuss the challenge and its importance to the Nation, and capture the nature of the problem in a human-centered problem frame. You will provide any framing tools you created in this process as an appendix.

INTENDED LEARNING OUTCOMES

Through your active participation with this final project module you will:

- Reflect on qualitative data and experiences to appropriately "frame" a design problem from stakeholder perspective.
- Appreciate the importance of recognizing personal biases and traditions in problem framing.
- Implement problem framing methods to create an appropriate initial project brief for your final project.

DELIVERABLES

- A three page (approximately) **introduction, background research on the Natio**n (think of the first assignment as an example).

- **A description of the design challenge (also known as a challenge brief)** as understood through stakeholder engagement. (as many pages as you need to adequately portray the challenge).

- **A well-formulated problem frame** that is considerate of the hallmarks of a good frame.
(State your problem frame in the form of "Who Needs What Because Why?" and "How Might We?" Statements).

Attach as Appendices:

- Any **framing tools** used to help develop empathy and understanding with stakeholder perspectives (ie empathy maps and user personas), or determine the appropriate abstraction and ambition levels.

- **Individual Module Reflections** (1-page from each team member): What was familiar, what was surprising/challenging, and what do you want to know more about? (follow the same structure as the weekly reflective papers).

Due Date: February 9, 2022

FINAL PROJECT MODULE 2
DUE MARCH 9, 2022

ENGAGEMENT STRATEGY, RESEARCH OVERVIEW, INSIGHTS, AND GUIDING DESIGN PRINCIPLES

"We need to start building from the foundation of two systems understanding each other. And once we can build that foundation, then the first thing we should start working towards is the concept of trust and respect"
- Dr. Reg Crowshoe

MODULE DESCRIPTION

In this module you will draw on your learning from class about co-design, ethical space and qualitative research methods to discuss your 'ideal' engagement strategy with the Nation (provided you had more time). You will also discuss your actual engagement process and summarize any background research or fieldwork you have conducted about the challenge or similar initiatives elsewhere. You may consider the cultural acumen training, Ethical Space workshop, KAIROS Blanket Exercise, Project Kick-off Ceremony, and Community Tours as part of your field research. You will provide a list of insights you have made from your research and the insight based guiding design principles that came from them. Discuss any design tools/methods you used to help create your insight based design principles.

INTENDED LEARNING OUTCOMES

Through your active participation with this final project module you will:

- Experience how the technical capabilities of engineers can be augmented with a broader view of how engineers think, feel, and show up in the world.
- Appreciate the importance of appropriate engagement protocols and relationship building with Indigenous Nations.
- Analyze and synthesize qualitative data in order to develop insights and guiding design principles that will help in concept generation.

DELIVERABLES

- Revised Problem Frame in the form of Who Needs What Because Why, and How Might We...

- A "**high level" outline of your team's *ideal* engagement strategy**. This outline may include how you would employ Ethical Space and Co-design frameworks. In your submission, identify what questions you have, and how you would explore them. Ask yourself: What do we really need to understand to make the biggest difference on this challenge? What do we want to learn more about in the to help us better understand where there are leverage points? *Draw on resources provided on Ethical Space, Co-design, and engagement strategy examples.*

(Think about the concepts that constitute qualitative rigor: triangulation, saturation, and representation. hint: see resources provided on Ethical Space, Co-design, and engagement strategy examples)

- A thorough ***secondary research (ie. desk research) report*** exploring questions relevant to the design challenge.

- A description of the actual engagement activities that have been done to date, or are planned for the future.

- **Three-to-five *insight based* "Guiding Design Principles" created by analyzing and synthesizing qualitative data (qualitative interviews, site visits, observations, relevant secondary sources, etc).**

Please include relevant appendices that show your Methods for data gathering, and data Analysis and Synthesis

Due Date: March 9, 2022

FINAL PROJECT MODULE 3
DUE APRIL 14, 2022

RAPID PROTOTYPING, TESTING, AND REFINED DESIGN CONCEPT

MODULE DESCRIPTION

Once you have developed an appropriate problem frame (module 1) and produced insight-based guiding design principles (module 2), you will begin to explore the concept “solution space”. This is done through an iterative process of divergent and convergent thinking. “Rapid prototyping” is a helpful tool during this process. Rapid prototypes are rough, low-fidelity solution attempts that are just refined enough to see if a solution is worth further exploration based on user feedback (Dunne, 2018). They are used as a means of concept validation with small groups of participants in a way that does not influence the dynamics of the system at large. Each attempt raises further questions about the nature, scope, and impact of the problem (Dunne, 2018). For designers, a prototype is a means to generate insights. The prototype itself is of little value, but the understanding of the problem and the users that these low-fidelity prototypes create is of immense value. Designers use Rapid Prototypes as critical vehicles for thinking; making is about understanding problems and solving them at the same time.

In this module you will discuss your rapid prototyping and concept selection process. You will choose one concept based on user feedback and develop a more refined prototype (something that could be used to create a "Class C" cost estimate). You will also describe at least two additional concepts to a rough conceptual level (Class D). You will also produce a final technical report that details the proposed design. The final report must be in a format that is of use for the Nation and could be used as the basis for future funding applications. You will also produce a high-level executive summary (non-technical) as a “Nation Facing” document that can be shared with the general Nation membership.

INTENDED LEARNING OUTCOMES

Through your active participation with this final project module you will:

- Experience how the technical capabilities of engineers can be augmented with a broader view of how engineers think, feel, and show up in the world.
- Employ technical competencies and human-centered design techniques such as rapid prototyping in an Ethical Space framework in order to develop engineering designs that satisfy community specified needs with appropriate attention to health, safety, economic, environmental, cultural and societal considerations

DELIVERABLES

Part 1: Concept generation, rapid prototyping, and concept selection process

- Your **concept generation, rapid prototyping, and concept selection process.**
(If you have made any significant pivots or re-frames since the first two reports, please discuss them in detail in this report, ensuring that you use user-feedback to justify these pivots).

- At least **two alternate design concepts** and how you used rapid prototyping and stakeholder-feedback to test and evaluate these designs.

Attach all design methods and outputs as relevant appendices.

Part 2: Technical Report

- A **feasibility study** that could be used as the basis of a submission to ISC or other funding program. The feasibility study should include recommendations and preliminary designs for the project your team is working on. Give an in-depth preliminary technical description of the chosen design, along with a class-C cost estimate.

- A **"roadmap"** with recommendations for future implementation, project timelines, and potential funding sources.

Part 3: Executive Summary

- A **high-level executive summary** (non-technical) as a “Nation Facing” document that can be shared with the general Nation membership.

Due date: April 14, 2022

Appendix D: Ethics Documents

University of Victoria

Office of Research Services | Human Research Ethics Board
Michael Williams Building Rm B202 PO Box 1700 STN CSC Victoria BC V8W 2Y2 Canada
T 250-472-4545 | F 250-721-8960 | uvic.ca/research | ethics@uvic.ca

Certificate of Approval

PRINCIPAL INVESTIGATOR	**Phalguni Mukhopadhyaya** (Supervisor)	**ETHICS PROTOCOL NUMBER** Expedited review - delegated	**21-0387**
PRINCIPAL APPLICANT	**Eric Wilson** **PhD student**	ORIGINAL APPROVAL DATE	01-Nov-2021
UVIC DEPARTMENT	**Civil Engineering CIVI**	APPROVED ON	01-Nov-2021
		APPROVAL EXPIRY DATE	31-Oct-2022

PROJECT TITLE **Integration of Emotional Intelligence in Engineering Design and Education**

RESEARCH TEAM MEMBERS
David Dunne - Co-Supervisor, University of Victoria

DECLARED PROJECT FUNDING **None**

DOCUMENTS INCLUDED IN THIS APPROVAL
tcps2_core_certificate.pdf - 23-Aug-2021
Appendix 1 - Neutral third part e-mail disclaimer.pdf - 01-Sep-2021
Appendix 2 - Description of the study to students.pdf - 01-Sep-2021
APPENDIX 3 - Pre and Post Assessments.pdf - 01-Sep-2021
Appendix 4 - EITC Sample Student Comprehensive EQ-i 2.0 Report.pdf - 01-Sep-2021
MHS_Reliability&Validity_Article_Final.pdf - 01-Sep-2021
Appendix 7- Verbal Consent Script.pdf - 01-Sep-2021
Appendix 6- Study Group Declaration of Understanding.pdf - 01-Sep-2021
Appendix 8- Withdrawl form.pdf - 16-Sep-2021
Appendix 5- Control Group Consent.pdf - 29-Oct-2021
Appendix 9 - Clarification on Item 3.pdf - 29-Oct-2021

CONDITIONS OF APPROVAL

This Certificate of Approval is valid for the above term provided there is no change in the protocol.

Modifications
To make any changes to the approved research procedures in your study, please submit a “Request for Modification” form. You must receive ethics approval before proceeding with your modified protocol.

Renewals
Your ethics approval must be current for the period during which you are recruiting participants or collecting data. To renew your protocol, please submit a “Request for Renewal” form before the expiry date on your certificate. You will be sent an emailed reminder prompting you to renew your protocol about six weeks before your expiry date.

Project Closures
When you have completed all data collection activities and will have no further contact with participants, please notify the Human Research Ethics Board by submitting a “Notice of Project Completion” form.

Certification

This certifies that the UVic Human Research Ethics Board has examined this research protocol and concluded that, in all respects, the proposed research meets the appropiate standards of ethcis as outlines by the University of Victoria Research Regulations Involving Human Participants.

Dr. Rachael Scarth
Associate VP Research Operations

Certificate Issued On: 01-Nov-2021