AI Adventure Camp: Developing Critical Thinking and Ethical Artificial Intelligence Literacy through Design Fiction and Digital Constructionism

by

Tess Butler-Ulrich

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Examining Committee:

Chair of Examining Committee	Dr. Ann LeSage, Ontario Tech University
Research Supervisor	Dr. Janette Hughes, Ontario Tech University
Examining Committee Member	Dr. Allyson Eamer, Ontario Tech University
Thesis Examiner	Dr. Peter Lewis, Ontario Tech University

The above committee determined that the thesis is acceptable in form and content and that a satisfactory knowledge of the field covered by the thesis was demonstrated by the candidate during an oral examination. A signed copy of the Certificate of Approval is available from the School of Graduate and Postdoctoral Studies.

Abstract

Artificial intelligence is an increasingly influential aspect of our lives. From GPS to Siri and Amazon Echoes, our data is collected, stored, and analyzed throughout the day. Despite the ubiquity of AI, most STEM curricula omit the social and ethical dimensions of interacting with AI and instead focus on developing digital skills, such as coding and programming. This may lead to a disparity between critical thinking and technical competency. It is urgent for youth to develop a balanced understanding of AI and the biases it can propagate to develop equity in STEM and propel comprehensive AI literacy in youth that blends technical competencies with critical thinking. Using the graphic novel Meehaneeto as a vehicle for these conversations, AI Adventure Camp aimed to facilitate conversations surrounding understanding the deeper implications of ethical and critical AI use through graphic novel narrative and building technical competency through coding challenges. This thesis explores the shifts in thinking that occurred over the course of the camp and examines the design challenges and successes of the first iteration of AI Adventure Camp.

Keywords: artificial intelligence; coding; constructionism; critical thinking; OST camp; STEM; virtual camp

Author's Declaration

I hereby declare that this thesis consists of original work which I have authored. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Tess Butler-Ulrich

Statement of Contributions

I hereby certify that I am the sole author of this thesis and that no part of this thesis has been published or submitted for publication. I have used standard referencing practices to acknowledge ideas, research techniques, or other materials that belong to others. Furthermore, I hereby certify that I am the sole source of the creative works and/or inventive knowledge described in this thesis.

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List of Abbreviations and Symbols

AI	Artificial Intelligence
AIL	Artificial Intelligence Literacy
AR	Augmented Reality
EAITs	Educational Artificial Intelligence Tools
ICTs	Information Communications Technologies
IoT	Internet of Things
OST	Outside School Time
STEM	Science, Technology, Engineering, and Math
STEAM	Science, Technology, Engineering, Art, and Math
STS	Science and Technology Studies
VR	Virtual Reality

Author's Note

The following research, in certain ways, concerns itself with gender inequity within STEM. In the academic literature surrounding this topic, the nature of gender is mostly delineated as boys and girls/men and women and is in turn, indistinguishable in context with biological sex. I would like to acknowledge that gender is separate from biological sex. Gender is a social construct and reporting "boys" and "girls" as if a dichotomous variable is not reflective of the amorphous and ever-shifting spectrum of gender identities. When referring to boys and girls and gender differences within the research, I am solely referring to biological sex. Similarly, terms such as "gender norms" to heteronormative societal standards of gender (i.e., "boy vs. girl, men vs. women") and are used solely to preserve consistency across research

Chapter 1

Introduction

1.1 Overview

This research explores the perceptions youth hold of AI and the shifts in thinking about AI that occur after the course of a five-day camp. As AI has become embedded in our everyday lives, it is crucial that educators gain critical insight into the ways in which students understand AI and how to facilitate learning experiences that develop critical thinking surrounding the ethical implications of AI. This has been largely unexplored in the current research literature. Despite the ubiquitous role AI has in society, a 2021 UNESCO report revealed only eleven countries have mandated AI curricula, with four more countries currently developing AI-based curricula, illustrating the lack of space AI literacy is currently afforded in the classroom (UNESCO, 2021). This study hopes to illuminate a group of youth's perspectives on AI and the shifts in thinking that occurred by the end of a 5-day camp focused on AI. The objective of the camp programming was to provide space for students to consider the social and ethical dimensions of AI, while also fostering technical competencies in coding. This work proposes that AI literacy is only comprehensive when both ethical issues and technical competencies are equally addressed. This work borrows the lens of critical theory of technology, constructionism, and design fiction to inform the development, analysis, and presentation of findings.

1.2. Defining Artificial Intelligence

Developing a precise definition for the term "artificial intelligence" is elusive. Due to the capricious nature of technology, there are limited ways to encapsulate artificial intelligence (AI) without omitting a new advancement, lens, or perspective. However, there are various definitions and conceptualizations that can perhaps aid an individual in detailing a close-to "whole picture" of AI. To begin, AI is often explained as a direct contrast to natural intelligence. Artificial intelligence is defined in the Google dictionary as, "the theory and development of computer systems able to perform tasks that normally require human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages." (Google, n.d.). Reading this definition may conjure visions of advanced, humanoid robots or perhaps disembodied voices that control cars and homes from the Cloud. Another definition reports AI as, "the capability of a machine to imitate intelligent human behaviour" (Merriam-Webster, n.d.). The context and definition of AI shifts within academic and scholarly spaces, Stanford University's Encyclopedia of Philosophy (2018) writes this about the phantomic definition of AI:

> Philosophers arguably know better than anyone that precisely defining a particular discipline to the satisfaction of all relevant parties (including those working in the discipline itself) can be acutely challenging. Philosophers of science certainly have proposed credible accounts of what constitutes at least the general shape and texture of a given field of science and/or engineering, but what exactly is the agreed-upon definition of physics? What about biology? What, for that matter, is philosophy, exactly? These are remarkably

difficult, maybe even eternally unanswerable, questions, especially if the target is a *consensus* definition.

Russell and Norvig's (1995) attempt at providing scholarly definitions of AI proposes that that there are four basic definitions, depending on context:

1. Human-Based and Reasoning-Based: Systems that think like humans.
2. Human-Based and Behaviour-Based: Systems that act like humans.
3. Ideal Rationality and Reasoning-Based: Systems that think rationally.
4. Ideal Rationality and Behaviour-Based: Systems that act rationally.

Stanford Encyclopedia of Philosophy notes that Russell and Norvig's definition can encompass most perspectives of AI, at least somewhat (2018).

The scope of artificial intelligence often reaches different heights than what one might typically expect. Human intelligence and functional cognitive ability are enormously varied and searching for a catch-all definition of both "AI" and "human intelligence" will ultimately fail to capture the full scope of human experiences. The definitions reported above may point to machines mimicking the entirety of the human brain, but this is a far cry from how conventional AI is applied in most contexts. Despite popular belief, AI is typically programmed to excel in one area of intelligence (e.g., decision making or speech recognition), where human (or natural) intelligence has a wider scope (e.g., humans are generally equipped for both decision-making, speech recognition, and other uncountable cognitive tasks). To further piece together a larger conceptual picture of AI, it may be helpful to consider the categorical differences in the varied types of AI. LearnX, a research dissemination project on teaching and learning AI, math, and coding, describes two different “containers” for AI: physical and digital. Physical AI is AI with a manifested “body” and includes machines like self-driving cars, robots, and drones. Conversely, digital AI lacks physical characteristics and instead functions solely in a digital space. Digital AI includes programs like image recognition software, chat bots, medical diagnostic tools, video games and algorithmic suggestions on Google or YouTube. The two domains of AI can further be categorized into “strong and weak” AI (learnx.ca). Strong AI refers to AI machines or programs that have the capacity to learn, behave, and construct knowledge like a human. Weak AI, perhaps intuitively, refers to AI that is designed to carry out pre-programmed tasks. As the discourse around AI grows, “weak” and “strong” AI are generally used less, with “narrow” and “broad” or “general” replacing them. Strong and weak AI are both sophisticated and complex systems and weak AI does not necessarily require the machine to be less intelligent or complex, and the terminology surrounding these words is shifting to reflect this (Walch, 2019). Moreover, despite what media representations may depict, physical AI is not exclusive to strong AI and digital AI is not exclusive to weak AI.

It is also imperative to delineate the difference between AI and machine learning. These terms may often be used interchangeably; however, using them as such may be viewed as erroneous as machine learning is a method (i.e., subset, domain, branch) of programming that trains machines to improve at a particular task. Instead, machine learning can be thought of as a topic of AI, rather than another term for AI itself. Moreover, as previously mentioned, the definition of AI may differ between social contexts and perspectives. For example, in colloquial terms, artificial intelligence may refer to any computerized program that has been developed to aid in, or assume responsibility for, an otherwise human-centred task; yet in a K-12 setting, artificial intelligence may refer to a series of block-coded algorithms that generate a series of numbers and may mean something else entirely to a computer science expert. Therefore, it may be of some importance to embrace the ambiguity of the term artificial intelligence and acknowledge the different forms it appears in various settings, instead of trying to develop a "one-size-fits-all" approach. It is less important to pinpoint a specific definition of what AI is or is not. Instead, the current work strives to explore youth's perceptions and personal definitions of artificial intelligence – in other words, what AI means to them.

1.3 Thesis Objectives

AI Adventure Camp was developed with the intent to provide an opportunity for participants to begin their critical explorations of artificial intelligence, as there are limited resources for this in the classroom. Due to the constraints of only five days, this camp was designed to be a starting point for participants to begin thinking and conversing about the ethical implications and social dimensions of AI. Because each participant would be at varying levels of familiarity with AI, it was determined that understanding the shifts in thinking that occurred over the course of the five-day camp would be valuable data in understanding what the general perceptions of AI are in youth, where their shifts in thinking about AI occurred, and what were the primary influences in facilitating those shifts. Further, because AI camp is a first-iteration camp, aimed at targeting technical competencies involved with AI literacy and critical thinking via the graphic novel *Meehaneeto* and digital constructionism, it was also determined that understanding how elements of camp supported these shifts in thinking for future iterations of AI camp and AI education programming.

AI is exceedingly prominent in our lives, manifesting as much more than physical robots and digital assistants. There are algorithms on popular websites, insidious data collection tools, and embodied applications that assist with common tasks like washing and drying hands in a public restroom. Despite the ubiquity of AI applications and the effect in our lives – whether it is large or small – youth's perceptions and overall comprehension of what AI is and how it directly influences them remains largely unresearched. Similarly, it is unknown how youth are applying critical thinking and discerning technology usage and AI-embedded programs. As the AI sector continues to grow and human society becomes enmeshed as Human-and-AI society, it is becoming urgent to examine how youth, the next generation of AI developers and regulators, engages with AI, how they currently use AI, and how they conceive AI so that any misrepresentations can be corrected, and AI literacy endeavours can be effective and comprehensive. Indeed, just as there are excellent representations of AI in media that illustrate speculative futures and possibilities of AI, there are also pieces of media that convey unrealistic portrayals of AI that paint images that are undiscriminating, lacking nuance and realism. Though media is typically marketed as purely entertainment, youth are susceptible to the influence of repeated narratives seen in mass media. This has been widely researched concerning how media has shaped youth's perspectives of race and gender (Scharrer & Ramasubramanian, 2015), and as discussed later, AI plays a role in sustaining both racial and gender inequities. Indeed, media literacy has reached its nexus: There must be an urgent call for accessible resources that address ethical AI and can support not only realistic representations of AI, but how AI perpetuates stereotypes and barriers, and how it can be used to overcome these challenges.

Moreover, despite AI as a topic within classrooms, the interventions and design models for supporting underrepresented populations in AI development are largely unclear. Although there has been progress in making AI more accessible to girls, such as the updates to PicoCricket that may appeal to a wider audience and the Technovation Girls program, there is an acute lack of resources developed with the clear objective to address girls' interest in AI. It is increasingly urgent to develop programs like Technovation Girls and to provide girls with access to accurate and reflective depictions of real women working in STEM – particularly artificial intelligence. As we enter an age in which we will become increasingly entwined with AI applications, it is crucial that we investigate multiple pathways for women and girls to generate interest and gain competence in technology and AI so that diverse perspectives can be included in the development of AI programs that will inevitably hold a growing significance in our lives. Moreover, girls, women, and marginalized communities are more at-risk of being underrepresented in data sets, resulting in AI bias that manifests in society in malicious ways (as AI-based discrimination). AI Camp used *Meehaneeto* and critical discussions to broach these topics in the hopes that participants would gain a more nuanced understanding of AI.

In summary, the purpose of this qualitative case study research is to:

1. Explore the perceptions youth hold surrounding AI and its use/presence in our societies.

2. To support youth's critical thinking through design fiction, ethical AI activities, and discussion.
3. To help build technical competency in coding as a dimension of comprehensive AI Literacy.
4. To examine shifts in thinking and how the camp supported these shifts.

1.4 Positionality Statement

AI has had a near-indescribable impact on our world, for better and for worse. There have been feats in science and technology that would not have been possible without AI-based systems, and health processes that have been revolutionized (Gurgitano et al., 2021), and yet, some AI manifestations have had negative repercussions in our real-world and help support oppressive systems that have been long-standing in societies. The gender gap in STEM, which is prominently seen in the technology sector, has reverberations in academic research circles (Abazi-Bexheti et al., 2019), tech policy design (Young et al., 2019), and manifestations of AI in society that place women at a disadvantage or, at least, not in the forefront of technology design. For instance, women are most often targeted by deepfakes (Dunn, 2021) and the underrepresentation of women in tech can lead to unfortunate manifestations of AI that directly oppose women's equity (Leavy, 2018). Additionally, as a maker myself, my goal is to provide opportunities for ethical and critical literacy through experiences that let students connect with their learning personally. This thesis wields digital constructionism (an approach often used in Maker pedagogies) as primary pillar of the theoretical framework that upholds the current research and seeks to blend critical theory of technology and digital making together to explore equity in STEM and STEAM education and contribute, however subtly, to the democratization AI education with the hope that future generations will be responsible, ethical, and equitable AI users, developers, and regulators.

Chapter 2

Literature Review

2.1 Overview of Literature Review

This literature review provides an overview and evaluation of the measures by which AI is being used in the classroom, with particular interest paid to the exploration of how AI is being taught to students in terms of technical skills and critical thinking and also girls' experiences in STEM. This search was conducted using the Ontario Tech UOIT online library, which accesses numerous research databases like EBSCO and Academic Search Premier, Google Scholar, and searches of articles' citations. Searches were conducted using combinations of the keywords: AI, artificial intelligence, elementary, education, ethics, critical thinking. Additional searches were conducted to explore the role of women in AI and used combinations of the following keywords: AI, artificial intelligence, elementary, education, ethics, critical thinking, girls, K-12, student perceptions, technology, women. Peer-reviewed articles were selected for review to ensure high-quality academic sources; however, due to the nascency of research surrounding AI as a teachable concept and the ethics of AI in K-12 education, journal-published papers are still limited. Therefore, papers presented at and submitted to legitimate scholarly conferences and relevant papers outside the scope of K-12 education were also included/considered on a case-by-case basis.

As described above, AI is a very broad term and can refer to a number of concepts and technologies depending on the author and there is no one-true definition (Kirsch, 1991; Wang, 2019). Further, the terms AI, robotics, and machine learning are often conflated and used interchangeably. (Dell, 2017). To provide some added clarity, machine learning is a type, or branch, of artificial intelligence that focuses on the algorithmic structures and data sets within AI applications (Nichols et al., 2019). Robotics is a disparate category, one that can be, but is not always enmeshed with AI. According to Queen's University's Faculty of Engineering and Applied Science (n.d.), robotics can be thought of as a subset of mechatronics that fuses the disciplines of mechanical engineering, electrical engineering, and computer science. Artificial intelligence, as previously discussed, is a broad term that changes depending on the context. Robotics and AI are, of course, compatible with each other. When AI and robotics meet, artificially intelligent robots are created (Brady, 1984). For the purposes of this paper, we will embrace the shifting definition of AI, and will offer precise definitions when available in the literature. In most instances, however, AI will broadly refer to any application using any branch of artificial intelligence technology – that is, technology programmed to think, act, or respond as a human.

2.2 The Role of Artificial Intelligence in 21st Century Societies

Whether one trusts it or not, AI is now enmeshed in our everyday lives. Even a mundane task, such as checking email or writing a paper for school has AI-integrated applications suggesting the user block a spam sender or change the phrasing of a sentence. Development of AI is now predicted to be led by an "AI first mindset", a term that has been popularized within online tech spaces, which stipulates that no novel technological application will be developed without exploring the potential for AI integration. This mindset replaces the once-popular "mobile first" mantra, when a sudden shift in websites such as Facebook and Google developed mobile-friendly apps (Gentsch, 2017, p. 256). In 2021, the Pew Research Center collected large-scale demographics concerning cellular device and smartphone usage. As of February 2021, 97% of American adults own cell phones. Within that 97%, 85% own smartphones. The role of the smartphone cannot be understated – banking, socializing, access to schools and classes can all be housed within a smartphone. In some cases, smartphones are the only link between an individual and digital spaces. Youth and Americans within a lower socioeconomic status are more likely than adults to be "smartphone dependent". Smartphone dependency refers to an individual who relies solely on smartphones to access the internet. They do not have access to broadband internet, nor do they own personal computer devices, iPads, or the like (Pew Research Center, 2021). Smartphones set in motion an enormous paradigm shift in how people access and interact with information, allowing the digital divide between those who had money for a computer and those who did not, to narrow. Mobile applications have established themselves as ubiquitous tools in our society and have helped developing nations make strides in their access to information and connect to other individuals around the world (Blaisdell, 2012). In certain instances, AI has quickly swept the world and some developing nations have not adopted earlier technologies in the chronological order the western world did. In India, for instance, landlines were not as popularized as they were in North America. Instead, there was a massive overtaking of cellphones. These booms in devices and technology that seem to skip over Western popularized precursors is called "leapfrogging" (Miller, 2001) and speak to how quickly the globalization of information can occur when there are efficient ICTs available worldwide. AI and the Internet-of-Things is an international topic of education that should be readily implemented so users are able to interact with ICTs effectively and responsibly while

The title of this section, *The Role of Artificial Intelligence in 21st Century Societies* refers to an enormous and complete shift that permeated (and continues to permeate) and shifted not only geographically, but in almost every aspect of our world. Because of the sheer influence of the internet, technology, and AI, it is impossible to name each and every way AI has impacted global society. Therefore, the present literature review outlines broad categories that group the purpose of the AI or ICTs.

2.2.1 Chatbots, Personal Assistants, Devices, and AI as the "Friendly Helper"

The literature in this section describes AI applications that are developed and utilized for helping or making personal human processes more streamlined, and "the efficient computer", the ways in which AI is developed to help business, science, and other sectors. Individuals in North American society interact with AI, largely, on a day-to-day basis – sometimes unbeknownst to the users, through automation within our daily lives, from digital assistants such as Siri and Alexa to more subtle mechanisms like the YouTube algorithm and targeted ads. In fact, Van Baker, VP of research at Gartner Global Research and Advisory, reports that the interest in Chatbots and associated technologies for customer service and sales increased 160% in 2018 (Gartner.com, 2019). Currently, approximately 40% of businesses in the US, EU, and China rely on AI Chatbots to handle customer service interactions and conversations in some capacity (IBM, 2020). It seems that

AI communication in consumer-based operations has become one of the primary methods of customer experience.

Similarly, digital personal assistants are nearly ubiquitous on any device an individual can purchase. Most phone operating systems (OS) have a brand-specific built-in assistant. For example, Siri, a personal digital assistant that was first launched in 2011 on the iPhone 4S, is automatically installed and functioning on all Apple devices. In a similar vein, the Google Pixel comes equipped with an assistant that responds to the words, “Hey Google”, or “Okay Google” (Google, 2020), and Bixby is the AI assistant for Samsung devices (Samsung, 2020). If one owns a PC with Windows 10, they can rely on Cortana (Microsoft, 2017). This feature, again, is built-in and automatically set to the “on” setting. This alone sends the message that explicit, communication-based AI is the default and that turning these assistants off is the other option – something an individual needs to go out of their way to disable. Technology infused with Smart Assistants and personified AI has become the default.

These personifications of algorithms and machine learning are common in North America, perhaps for good reason. The lifelike back-and-forth one can generate with personified AIs creates an explicit two-way interaction between the AI interface and the human, where the individual typically knows and consents to the communication taking place. These AIs can act as a stand-in when actual human interaction is not viable while providing the illusion of a “helpful robot”. Israel-based startup Cocohub launched its personal AI assistant builder in 2020. The platform requires no coding experience, allowing game developers, company programmers, and IT professionals to manufacture a personalized chatbot or assistant that is equipped to handle tasks such as scheduling, providing contact information, and advice (Cocohub, n.d.). The user can choose whether the AI interaction takes place with text, voice, or video (the platform generates a human-like avatar for the bot), perhaps marking the elevation from ChatBot to something more reminiscent of a natural human interaction in the physical world.

Japan is perhaps one of the first countries that comes to mind when envisioning a human-AI integrated society. In Japan, physical AI (i.e., robots) is now given a series of tasks for once-thought-to-be human responsibilities. Robovie, a humanoid robot developed by Advanced Telecommunications Research, acts as a museum tour guide and leads groups of children through the exhibits, offering a personified approach to integrative robotics that, through novelty and fascination, engages children in learning (Kahn et al., 2012). Companion robots are a popular market too, and robots are being used to provide support elderly people with dementia, provide company for car rides, and offer emotional comfort to those in hospitals or senior living facilities. These companion robots can be a helpful presence at all hours of the day and can supplement much needed connection that may be missing from some individuals' lives (Mahoney, 2019).

Personified, companion, and social AIs are joining consumer AIs in different sectors of society (Yang et al., 2018). As mental health issues are being brought more into the light, it is even proposed that AIs will step into the role of therapists, allowing for new and experimental modes of treatment, engagement for marginalized or hard-to-reach populations, and care targeted at specific disorders (Fiske et al., 2019; Liu et al., 2021). In spite of this, chatbots and personal phone and home assistants remain vulnerable to data breaches by hackers (Murugesan, 2019). There is an apparent disconnect between the use of AI in our daily lives and our understanding of the larger implications for security and privacy. With the advent of the internet, came the advent of malware, viruses, and ambiguous "hackers" who break into tech-based software on phones or computers (Jordan, 2016). The internet of things (IoT) is an information and communication technology (ICT) paradigm that can be conceived as interconnected devices and technologies or "smart" technologies (Park et al., 2020). At the onset of the IoT boom, developers failed to implement powerful security systems, leaving devices relatively unprotected in the event of a data breach. These security issues remain present in IoT connected devices and they are inherently difficult to correct (Yang et al., 2017). As AI integrates into IoT technologies, it is important to consider the limits of security and privacy and what is happening with the data accrued through usage.

One particular AI-based tool has taken the media by storm and its popularity has brought waves of scrutiny down on chatbots and general text-based AI applications. ChatGPT has become a notable name not just in educational spaces, but has reached levels of notoriety in households, newsrooms, and social media as well. ChatGPT has the ability to mimic human writing on a wide range of topics at the request of the user (Lund & Wang, 2023). Using a language model developed by OpenAI (ChatGPT's founding lab) known as Generative Pre-Trained Transformer, ChatGPT has an astounding ability to produce human-like writing that has skyrocketed the userbase of this program to over 1 million within the first week of its public availability (Mollman, 2022). This has disrupted the status quo of written-form content creation, as it can be asked to write anything from a blog to an academic essay. This presents unique challenges relating to whether using ChatGPT for work or school is moral and ethical, as limited effort is required to produce a sophisticated piece of writing (Khalil & Er, 2023). The ethical concerns are not only limited to academic integrity but extend to social and environmental provinces as well. Lund & Wang (2023) authored an in-depth examination of ChatGPT and noted that one of "the main limitations is that GPT models are based on a statistical approach that learns patterns from a large dataset of text, which can perpetuate biases and stereotypes present in the data" (p.4) in which the text produced may have the potential to reinforce social stereotypes by including or excluding certain narratives, lived experiences, and perhaps, in some cases, may generate offensive output. Further, though not yet conclusive, ChatGPT likely requires extensive amounts of energy to train and although "likely small at the moment, could rise as more people turn to it for day-to-day search" (Boudreau, 2023). The carbon footprint and environmental implications of AI on energy have been rising in recent years as light has been shed on the carbon emissions of AI-based tasks such as neural architecture searches have revealed to be both high and costly (Strubell et al., 2019; Zhou et al., 2021). Therefore, even AI-based applications that may be viewed as helpers or have personifications and explicit ways to help humans should be used with caution; it is through scrutiny that biases and ethical concerns may be identified and addressed.

2.2.2 Big Data, Science, Corporations, and "The Efficient Computer"

The global explosion of IoT has resulted in huge amounts of data being generated from people through multiple sources. The data produced from social networking, cell phone usage, PC, and other smart devices urgently requires more efficient methods of data congregation, analysis, and storage (Rahmani et al., 2021; Klein, 2017; Park et al., 2020). IoT and the interconnection of smart tech produces mass amounts of data that would not be able to be efficiently congregated or analyzed without AI. Concisely, big data allows for the data collected from IoT (which is a massive amount) to be analyzed. Ryax, a French tech company, writes this about the two:

> IoT and Big Data are two independent technologies that are inseparable from each other, to enable well-known technological advances. While the IoT would largely collect data from physical objects through different sensors, Big Data would allow faster and more efficient storage and processing of this data. (2021)

Both IoT and big data analytics rest upon a foundation of AI and machine learning. The explosion of IoT and the subsequent effects have resulted in rapid paradigm shifts in political, health, and economic sectors (Zimmerman, 2018). Hospitals use AI for medical diagnoses, predictions of ICU transfers, classification of clinical documentation, clinical workflow efficiency, prediction of risk for infections, and even use surgical robots to help improve surgeons' vision and precision (Davenport & Kalakota, 2019). There are uses for cancer diagnoses too, with AI programs detecting breast cancer risk in mammograms at 30 times the efficiency and 99 percent accuracy (Deniz, 2016). Further into the biological science space, the AI-mediated programs Alphafold and Alphafold2 are being used to predict protein folding patterns, leading to major advancements in science. "The protein folding problem" existed in biological science for 50 years, resulting from the inability to determine what unique shape the protein will fold into. In 1972, it was notably theorized that knowing the sequence of amino acids in a protein would dictate the structure (Anfinsen, 1972). Since this time, many scientists have laboured over methods of predicting the shape of a protein from its amino acids. Now that there is a promising solution in AI, there may be leading to major advancements in science (Senior et al., 2020).

2.2.3 Ethical Implications for Artificial Intelligence in 21st Century Societies

AI has been deemed as a new tool for social good, but this designation may be erroneous, or at the very least one-sided (Moore, 2019). Though AI now has a space in everyday institutions like museums and hospitals, there is a less reported side of AI as well. As previously noted, AI is a promising route to organizational optimization; yet it also confers unique considerations that pose problematic ramifications. One pronounced problem in AI development is AI bias. The concern over the role AI bias will play in distributing equitable healthcare is growing. AI bias has the ability to intensify systemic inequalities present in our society (Panch et al., 2019). As Roselli and colleagues (2016, p.1) state, "Even with careful review of the algorithms and data sets, it may not be possible to delete all unwanted bias, particularly because AI systems learn from historical data, which encodes historical biases." Because AI is not a replacement, a direct copy, or a transcension of human intelligence, the quality of algorithms embedded in AI systems is dependent on the data, samples, and information it is supplied with (Sun et al., 2020). If a program is developed with a lack of representative data in certain populations, the program will be less equipped to accurately recognize those populations. For instance, algorithmic decision-making has become widespread practice in human resources management due to its efficiency and cost-savings (Köchling & Wehner, 2020). AI analyzes productivity, allows companies to review large numbers of applications at once, and can even provide insight into employees who may be planning on leaving (Silverman & Waller, 2015). Therefore, we should forge carefully into the new era in which AI will play a forthright role in human relationships.

On the contrary, some also argue that AI actually increases objectivity, as it removes "humanness" from the equation, leaving little room for personal bias (Florentine, 2016). However, AI in its current form, is always created by a human, which despite the excitement that arises from the prospect of AI revolutionizing industries, increasing output, and improving efficiency, there is still some hesitancy that surrounds its inevitable place in our lives. Although some conclude that AI integrations are a solution for subjectivity in data analyses and removing personal biases from research (Florentine, 2016), this does not adequately address the ethical implications and threats of AI bias innately present in utilizing AI for decision-making processes. If AI is trained on incomplete, biased, or non-representative data, the output of the program will mirror this in the decision-making processes (Chandler, 2016). One instance in which social inequities were amplified through algorithmic decision making was the hiring algorithms employed by Amazon. The use of these algorithms led to large-scale discrimination against women applicants in the hiring process (Dastin, 2018). Chandler (2016) goes on to argue that AI is able to be discriminatory because of the real-world on which it operates, which is structurally inequitable, writing:

> Thus, the problem is not the black box, which is often more neutral than the human decision maker it replaces, but the real world on which it operates. We must design our algorithms for a world permeated with the legacy of discriminations past and the reality of discriminations present (p. 1025).

Chandler then goes on to poignantly state, "The possibilities of discriminatory manipulation are legion." (p. 1026); it seems all too easy to embed prejudice within technology. In the case of Amazon, the reason this large-scale discrimination happened was due to an incomplete, or biased, dataset. The algorithm was trained using a 10-year data set consisting of previous applicants' resumes. Applicants in the past had been mostly male. This led to the algorithm developing biases against terms like “women’s club” (Dastin, 2018). As Chandler (2016) notes, we must recognize the systemic inequalities in our societies, and be prepared to recognize and swiftly amend any discriminatory algorithms or AI biases before they are put into place – unlike Amazon, who only discovered and retracted its gender-biased algorithm after it had made recommendations to recruiters (Dastin, 2018).

From the Gartner Information Technology blog, Bradley (2021) provides a succinct summary of the ethical AI cycle: “Real world bias is reflected in data bias is exposed by algorithmic bias is acted upon by business bias which impacts real world bias”. In other words, the programmer or human who sits at the starting point of research and development behind AI, holds their personal human bias – whether that bias is conscious or unconscious, it has been weaved from their particular social and cultural background – which is then embedded into the algorithm they create, perhaps under or over representing certain categories of data, which is put into practice by businesses or organizations, which reinforces systemic biases in society. The case of Amazon, above, is an excellent example of this cycle in practice. As corporations are often integrated with AI-based applications for efficiency and optimization, it is rather unlikely that Amazon is the only organization that implemented biased AI applications. Generalizing a similar situation to a large scale, it is easy to see how AI can uphold oppressive systems and barriers to equity.

There are further implications that stem from utilizing AI applications for ethically ambiguous purposes. China has implemented a social credit program in which information technology applications and artificial intelligence are used in the monitoring of citizen behaviour with the stated goal of increasing social integrity, accountability, and citizenship. However, this also begs the question of the human right to privacy. Although some suggest that the social credit system is related to economic and educational activities rather than political (Liang, et al., 2018), and many of the goals for this system aim to positively impact social behaviour and society at large, there is still concern over the implications of collecting citizen data at this scale may bring the opposite of the desired effects (Chorzempa et al., 2018) and does leave unanswered ethical queries.

Recently, AI is being used to produce products known as "deepfakes". Deepfakes use learning models to "swap" or superimpose faces of people or characters to create videos or images that are deceivingly realistic looking. Deepfakes synthesize a video or image of person doing or saying something that did not actually occur using processes called Generative Adversarial Networks, or GANs (Goodfellow et al., 2014). The process of creating deepfakes, though once available to only the most expert programmers, is now accessible through apps and websites that allow users to create their own (Meskys et al., 2019). The democratization of deepfakes yields potential to embolden the already abundant amount of "fake news" – a term popularized during the 2016 election in America (Quandt et al., 2019) and refers to the spread of misinformation – that perpetuates and thrives through digital media. There have been cases in which political figures have been "deepfaked" so as to appear to confess political views that contradict their own. Politicians such as Volodymyr Zelenskyy, Joe Biden, Donald Trump, Boris Johnson, Nancy Pelosi, and Barack Obama have all been featured in deepfake videos (NPR, 2022; Al-Sibai, 2022; BBC, 2019; CBS, 2019; Vaccari et al., 2020). Political deepfakes can impact how people evaluate and determine trustworthy news (Vaccari et al., 2020). However, perhaps surprisingly, it is not politicians who suffer the most at the hands of deepfakes. Women are the most targeted demographic of deepfakes, often with the aim of sexual exploitation of their likeness (Dunn, 2021). Not only are women the primary victims of deepfakes, the overrepresentation of men in the development and regulation of technology has potentially severe consequences for women: "Artificial intelligence is increasingly influencing the opinions and behavior of people in everyday life. However, the over-representation of men in the design of these technologies could quietly undo decades of advances in gender equality" (Leavy, p.1). Deepfakes and fake news perpetuated through social media algorithms currently influence youth's ability to discern reliable information on the internet. The literature makes clear that there are two sides to the story of AI, but it is still unclear how youth conceptualize or recognize these concerns and take action to mitigate them and keep data safe and whether or not misinformation succeeds in creating more social and political division among youth specifically.

Intuitively, individuals hope data that is congregated by corporations is kept safe. The act of hacking, which Erickson (2008) refers to as an art, perhaps has cultural associations of being a wholly unethical practice, has recently expanded into acts of social good. Erickson, however, also argues that information should be accessible and free for all, and that hacking is an act of good. Though outside the scope of the current research, hacking plays a pivotal role in the conversation concerning data, privacy, and AI. Civic hacking is a term that refers to the process of using hacking and data breaching to further political transparency and equity (Shrock, 2016). The internet and the aggregation of private information provided the means and motive to use hacking skills to access confidential files and personal data, but the same technology also allows civic hackers to participate in a form of digital and political activism. A more fitting and popular monicker for civic hackers, perhaps, is "hacktivist": someone who used technology-based skills to promote political agendas or social change (Mikhaylova, 2014). It is practices such as "hacktivism" that blur the lines between democratization of AI and the unethical practices of using AI to cause harm and spread misinformation to the public. Hacktivism and hacker culture have brought hacking into a more mainstream and positive light, even being adopted in educational spaces and has been positioned as a tool to merge develop social bonds and create personal networks (Shrock, 2014). Hacker cultures have been examined in relation to making and makerspaces, both of which help foster STEM-skills, design thinking, co-construction of knowledge through hands-on experiences, creativity, tinkering, and exploration (Hughes et al., 2018). The positive hacking movement can be viewed as an act of resistance of sorts – It is a movement in which the goal is to democratize technology and information, a cry for creative freedom, and a push against the systems that aim to keep the status quo and the inequity it bears. Whether hacking is done for pure exploration in a makerspace or political reasons is essentially play and allows youth to reclaim "some degree of freedom regarding their choices and behaviours" (Donovan & Katz, 2009) in a modern society that is brimming with surveillance, both digital and otherwise. Hacking, which many associate with unethical practices and invasions of privacy and security, can be a rich learning experiences that helps youth develop connections and build social circles. Technology and its associated processes, such as hacking, are not inherently moral or immoral, but it is based on the morals and decisions of the users. It is up to the users to program, hack, build, and design according to an ethical standard that values social good and social progress.

2.3 Artificial Intelligence Applications in the 21st Century Classroom

When something like artificial intelligence revolutionizes society in such a significant way, classrooms are sure to feel the reverberations. AI has taken classrooms in North America by storm and begun redefining the educational landscape. The present research focuses on AI as a theoretical concept to teach as well as AI-based content to better understand the mechanics. Therefore, the ways in which AI is being utilized as a tool for pedagogy and efficiency in the classroom is somewhat outside the scope of this paper. Nevertheless, it is a topic with much significance to the broader conversation of the ways AI impacts society. For instance, interactive learning environments (ILEs) ease the process of personalized assessment and mentoring, and intelligent tutoring systems (ITSs) can efficiently generate feedback and scaffolded steps towards a particular goal (Chassignol et al., 2018; VanLehn, 2011) have made room for themselves among modern teacher toolkits. Chassignol and colleagues (2011) note that assessment, content, teaching methods, and communication within education are greatly affected by AI implementations. Succinctly, AI has produced an educational paradigm shift that spurred the transition from manual and laborious processes to automated, quick, and easy processes. However, AI integration in pedagogical tools, or educational AI tools (EAITs), is not as readily accepted in classrooms as they are in modern day-to-day life (Choi et al., 2022). Trust plays a prominent role in the adoption of new technologies in workspaces, and there are many misconceptions and misinformation surrounding the role of AI as a tool for education, leading many practitioners to steer away from utilizing AI-based approaches in their personal professions (Nazaretsky et al., 2021). Education is one sector in which AI has had a great impact, yet whether educators trust AI approaches or not is still not entirely clear. Rienties (2014) examined academic practitioners' resistances to using online tools to evaluate student work, finding that despite the affordances of online evaluation tools, the respondents noted negative experiences with the transition from traditional methods of assessment to digital. Students have been shown to be more flexible and willing to learn and adopt new technologies, while instructors, teachers, and professors may be less inclined to do so (Hanson, 2009; Nazaretsky et al., 2021; Rienties, 2014). This resistance may be due to the organizational leadership of a school, adversity to change, personal perspectives of technology (Howard & Mozjeko, 2015) and beliefs related to self-efficacy (Holden & Rada, 2011). Thus, it is important to provide teachers with relevant and digestible information related to AI so they may better integrate AI into their content with confidence and clarity.

2.3.1 Defining Artificial Intelligence Literacy

Interestingly, the literature on AI in classrooms seems to be divisible into two broad categories: AI as a tool and AI Literacy. Each of these categories can be divided into two narrower dimensions. Within the category AI as a tool, research and emergent classroom trends seem to delineate between AI as a tool for teaching, which focuses on applications that aid teachers' pedagogy and assessment, and AI as a tool for learning, which focuses on using AI-based resources to improve student outcomes. These resources may be using augmented reality (AR) or virtual reality (VR) to increase motivation or may reference softwares such as intelligent tutoring systems (ITSs) that provide automated targeted feedback. These resources are not necessarily used in the classroom with the specific goal to improve understanding of AI – instead, AI is a means to an end. In the research that looks at the second category, AI literacy, or developing a deeper knowledge of AI principles, there seem to be, again, two distinct dimensions. The first dimension of technical competency focuses on using or studying computational thinking, computer science, machine learning, robotics, and math as it relates to AI. Secondly, critical thinking is concerned with examining the social and ethical dimensions of AI. Both of these categories contribute to the promotion of artificial intelligence literacy (AIL) in that AI is the focus of education, rather than a tool for education. Below are two charts that showcase the distinction between the dimensions of the literature. The first table illustrates AI as a tool and the two disparate ways AI is commonly used in classrooms. These charts were created based on the findings of the present literature review.

Table 1.1

Table illustrating the distinction between AI as a tool for teaching in the classroom and AI as a tool for learning in the classroom.

AI as a Tool in Classrooms	
AI as a tool for teaching	**AI as a tool for learning**
Using AI to improve efficiency, accuracy, and effectiveness of teaching strategies and pedagogical endeavours in classroom or education environments. Examples: • Interactive learning environments • Automated feedback applications • Course design "eLearning" tools	Using AI to improve motivation, understanding, and achievement in education for students. This does not necessarily mean AI is being utilized to further understanding in AI and AI concepts. Students can be engaged in AI-based applications without explicitly realizing they are using AI. Examples: • Intelligent tutoring systems • AI-based games that focus on curriculum content/educational topics • Interactive robots • AR/VR systems

Table 1.2

Table illustrating the two distinct dimensions of Artificial Intelligence Literacy in K-12 classrooms identified by the literature review.

Artificial Intelligence Literacy	
Technical Competencies	**Critical Thinking**
Using computer and technology-based skills to accomplish goals and obtaining strong working knowledge of principles of computer science or using technology. Examples: • Meeting coding expectations in the Ontario Curriculum • Developing understanding of programming, machine learning, math, and computer science principles • Opportunities to "make" and "tinker" with robotics • Using coding applications such as Scratch	Examining AI as both a theory and concept in relation to the role it plays in societies. • Examining how algorithms can be biased, affect daily life, and influence media consumption • Investigating the social dimensions and ethics of AI, including equity, privacy/security, and who is responsible for the development and regulation of AI • Social, environmental, and physical implications of AI • Exploring critical digital citizenship

The first broad category of literature that emerges when searching for literature on AI in classrooms contains research that explores AI applications, tools, and digitally-based programs as a tool or aid for teaching and learning processes, usually with curricular ties. Recently, these AI applications have become increasingly common in elementary, secondary, and post-secondary educational settings. These insights allow a glimpse into how AI is being utilized in classrooms currently. Interestingly, much of the research on AI as a tool in pedagogical processes is based in North America, whereas literacy has a larger international scope despite most AI curricula being American-developed (Choi & Park, 2021). To better understand the categorical division between

AI as a tool and AI literacy, consider the delineation between "Robotics in Education" and "Education in Robotics" (Alimsis, 2012). "Robotics in Education" refers to the use of robotics to support pedagogy and learning whereas "Education in Robotics" refers to training individuals to use robotics. The same can be applied to AI as a tool and AI literacy – AI as a tool is something that supports learning in areas of education not exclusive to machine learning, computer science, programming, or math. This may be something like learning management systems (LMS), augmented and virtual reality (AR and VR, respectively) platforms used to learn about history or geography, or AI-generated feedback. These examples could be further subdivided into "AI as a tool for teaching" (LMSs and automated feedback programs) and "AI as a tool for learning" (AR and VR platforms). AI, utilized as a tool for teaching and learning, has made incredible impacts in the classroom, but using AI as a tool for teaching and learning does not necessarily include AI literacy. The literature seems to reveal that AI literacy does not have a widely accepted academic definition but can be thought of as an individual's understanding of both the mechanics of AI and societal implications of AI. For the purposes of this literature review, these two categories can be labelled as "technical competency" and "critical thinking", each containing its own concerns and considerations. Though AI Literacy is not a particularly common term, it will be used in this literature review as it succinctly envelopes these two categories (technical skills and critical thinking) into an overarching framework that aims to reach a singular goal (understanding the multifaceted subject of AI). AI has currently taken off in classrooms as a tool to further teaching and learning processes, as the previous section outlines. There are limited studies on AI literacy itself, perhaps due to the undefined nature of the term and the nascence of AI (as a teachable concept) in the classroom. Choi and Park (2021) note that elementary education for AI, when implemented, is often divided into three categories: "understanding AI, understanding AI principles, and application of AI" (p. 2). Despite these three categories and the general usefulness of this proposed framework, it still lacks unified domains of knowledge that include ethical and social implications stemming from critical thinking.

AI is not only an applied application in the classroom to help streamline and support processes but also a concept to understand and manually practice. Despite the aforementioned significance to future job markets and society at large, explorations of students' understanding of AI is just now burgeoning. As AI is only becoming more enmeshed with societal systems, it is crucial that educators are facilitating discussions and learning opportunities that allow students to build skills related to practical AI. As Choi & Park (2021) described, individuals who "conquer AI will hold the hegemony of the world in the future" (p. 1), it is important to gauge student understanding and develop promising practices to teach AI conceptually so that they may be fully equipped to enter a world in which skills related to AI will become increasingly relevant and valued (Burgsteiner, 2016).

Moreover, as AI is a branch of computer science, it is naturally a topic in computer science courses, especially at higher levels. Elementary schools in Canada typically lack dedicated computer science courses, and so, AI may be relegated to supporting the development of competencies in other subjects. However, in 2020, the Ontario Mathematics Curriculum was updated to include mandatory coding, beginning in grade 1. This update may provide increased opportunities to explore technical skills related to AI through coding, programming, and computational thinking.

Technical competency building courses or projects often focus on specific domains of AI, for instance, developing understanding of algorithms, reinforcement learning, or machine learning.

Concisely put, critical thinking is the second half of AI Literacy along with technical competency. Critical thinking is currently an under-researched area within AI Literacy, despite this skill being necessary to develop a holistic understanding of AI and its implications across contexts. Therefore, it could be proposed that AI Literacy (AIL) is a combination of utilizing AI as a tool (using AI efficiently), understanding foundational AI concepts, such as machine learning and coding (technical competency), and the ability to examine AI in society (critical thinking). Twenty-first Century Skills are promoted in a 2016 Ontario Ministry of Education (OME) Document. This document outlines six critical competencies that are increasingly valued in Western societies. Within the policy document, the definition of critical thinking is borrowed from Fullan's (2013) work: "The ability to design and manage projects, solve problems, and make effective decisions using a variety of tools and resources" (p. 12). The document proposes that these competencies are a prerequisite to succeed in our current world and that educators must equip learners with this particular set of skills. The full six 21st-century competencies are critical thinking, communication, collaboration, creativity, innovation, and entrepreneurship (MOE, 2016). Critical thinking, in particular, is important to develop within the context of AI literacy so that students have a fuller understanding of the ways in which AI impacts both their daily lives and society at large. AI is promising when examining student critical thinking because there are multiple domains that need to be examined from political, economic, and social perspectives while also holding its position as a relevant 21st-century topic. Tools that develop critical thinking, in particular, can be described as, “Mindtools” which function to scaffold different forms of reasoning (Jonassen, 1999; Jonassen, Carr, & Yueh, 1998). Technology is regarded as a valuable Mindtool to develop critical thinking because it can position students as designers, constructors, and producers of knowledge (Jonassen, 1999), especially if students are prompted to explicitly think about how they solved AI-facing challenges (Kahn & Winters, 2021).

2.3.2 AI Literacy Frameworks

Though classrooms are implementing AI for diagnostics, learning management, and overall enhancing the teaching and learning experience, there is also a secondary use of AI. Students may build or use AI to develop a deeper understanding of and grow AI-related competencies. Platforms and tools such as Scratch, ViPER, Minecraft, and PopBots allow students the opportunity to engage with AI critically through experiences that activate situated cognitive processes. For instance, when using Minecraft or Scratch, students are actively embedded in the learning process; users are trying out what works and what does not work with their code and automating processes.

These uses of robots and games in the classroom rarely mirror real-world or balanced perspectives of how AI influences daily life. In order to sustain AI literate students, they must have the freedom to explore realistic examples of AI applications. Hollywood portrayals of AI often showcase a narrow scope of what AI might look like in the future: exaggerated, humanoid, programmed with explicit intentions. These seemingly hyperbolic tales may have significant impact on impressionable youth, ultimately resulting in narrowed and unrealistic perceptions of

AI. AI in our everyday lives has a tendency to be more subtle, through YouTube algorithms, face detection softwares, and personal assistants, and youth often cannot identify the actual instances in which they engage with AI (Hasse et al., 2019). However, these stories also serve as a metaphor for the current state of AI-human interaction and also as cautionary tales of possible futures if AI is developed recklessly. Therefore, it is imperative that youth are exposed to these narratives and what they represent while also developing a realistic understanding of how AI functions in their daily lives. As we move into an era in which AI applications will only become more prevalent, it is crucial that youth have the tools and understanding to navigate AI ethically and responsibly. In order for this to be achieved, students must be provided with sufficient opportunity to investigate not only the technical aspects of AI but also the philosophical and ethical implications of AI use.

Further, it has been suggested that AI should be observed as a critical indicator of national development (Choi & Park, 2021). Even so, most nations lack accessible and communicable goals for society to achieve through AI. With the development of AI rapidly evolving, many aspects of the modern classroom have been transformed. Using AI to develop both teaching and learning solutions demonstrates the potential to transform educational paradigms globally. Students in the current K-12 pipeline have close and personal relationships with both technology and AI, thus will have divergent experiences with AI than previous generations (Williams et al., 2019) and their perceptions of AI may differ. This may call for the development of AI curricula, frameworks, and learning opportunities specifically designed with current and future K-12 students in mind, with attention paid to their specific challenges and needs. This may be achieved by providing students with ample opportunities to develop critical thinking skills within the context of developing and regulating AI and promoting skills and competencies related to digital citizenship, something that continues to grow in . To ensure that educators are able to design learning opportunities with these considerations in mind, there have been some (albeit limited) frameworks and curricula presented.

One such framework is AI4K12. AI4K12 is an American AI curriculum developed in part by the Association for the Advancement of Artificial Intelligence and the Computer Science Teachers Association. It aims to develop national standards of AI education for K-12 students. AI4K12 outlines five "big ideas" (Touretzky et al., 2019; AI4K12, n.d.) in AI:

1. Perception: The first idea stresses the notion that computers perceive the world using sensors and specialty programming. Perception allows the computer to pick out relevant data from the sensory input. This allows the computer to "see" and "hear".

2. Representation & Reasoning: The second idea stresses the relationship between the representations the computer conserves and how they are used in reasoning. This idea emphasizes data structures, algorithms, and internal systems of information and organization. Agents maintain representations of the world and use them for reasoning.

3. Learning Computers: The third idea stresses machine learning and the processes by which computers can learn from data. This data can either be supplied by humans, or the machine can procure the data itself.

4. Natural Interaction: The fourth idea stresses the notion that computers use different kinds of information and knowledge to interact with humans. Most intelligent computers require the ability to hold a 2-way interaction with humans, recognize facial expressions, and even make inferences based on social conventions and culture.

5. Societal Impact: The fifth idea stresses the societal impact of AI, considering both the positives (e.g., efficiency and accuracy in healthcare and medical processes, training AI to do tasks unsafe or impossible for humans) and negatives (e.g., algorithmic bias). As AI4K12 notes, it is critical to discuss the ethics and impacts of AI on society and also develop criteria for "ethical design and deployment of AI-based systems" (AI4K12, n.d.).

This holistic approach to AI integrates both science (1-4) and ethics and critical thinking (5). Canada is a leader in the development of AI (Invest in Canada, 2021; CIFAR, n.d.), yet there are limited Canadian AIL frameworks that reflect this; A nation that undertakes the development and implementation of AI, should have education strategies to match. Further, there is no established agreement on artificial intelligence or even what computer science skills and competencies should be or at what grade they should be taught. Canada Learning Code notes in their curriculum that computer science frameworks are disjointed in Canada: some students are only taught about the technical aspects of computer science, such as coding and machine learning, whereas other students are taught more about digital citizenship and responsible navigation and use of technology. This leaves certain students at a disadvantage and makes AI education fundamentally inequitable.

To address this issue, in 2020, Canada Learning Code launched Learning for the Digital World: A Pan-Canadian K–12 Computer Science Education Framework, the first of its kind. As Canada lacks a consistent elementary computer science and artificial intelligence curriculum in every province (for instance, computer science is not offered until high school in certain provinces), Canada Learning Code aims to bridge the gap by providing accessible and equitable guidelines for AI literacy. Similar to AI4K12's framework, there are five skills (referred to as "focus areas" in the framework) upon which this curriculum is built.

Programming: The first principle is centred on building coding competencies through engaging activities. Students learn about data structures, algorithms, debugging, and modelling and abstraction.

Computing and Networks: The second principle is centred on digital literacy. Students explore connections between devices, troubleshooting, hardwares and softwares, and cybersecurity.

Data: This third principle is centred on developing an understanding of data – data storage, the collection and organization of data, applications of AI, and data governance.

Technology and Society: The fourth principle is centred on developing a critical lens when exploring AI. Students learn about ethics, laws, and safety, the ways in which technology impacts the planet and environment, digital communication, and technology and wellbeing.

Design: The fifth principle is centred on designing workable AI applications that are in line with the principles of good user design, universal design, and visual design.

Canada Learning Code offers, in addition to the five skills above, six capacities that are required to meet the needs of an ever-changing world. These six capacities are discovery, creative problem solving, collaboration, critical thinking, perseverance, and citizenship. These are similar to the 21st Century Competencies (Ministry of Ontario, 2016), in that they reflect contemporary values of a world in which skills that are related to innovation and flexibility are held in higher regard than ever before. Jobs will become increasingly intertwined with technology, robotics, and AI and these skills are critical to the success of future workers (Zimmerman, 2018).

Due to the lack of a unified framework, educators can also choose to incorporate the ISTE standards for students as benchmarks for AIL. These standards place emphasis on digital citizenship, guiding educators to provide opportunities for students to develop safe, responsible, and productive digital skills. Van Brummelen (2019) provides other tools, ideas, and activities to further the equity and democratization of AI. However, there are still limited options for Canadian AI literacy frameworks and even less options that interweave both technical-based skills and ethical/critical thinking.

2.3.3 Technical Competency and Game-Building for AIL

Constructionism is predicated on active learning processes and underscores students' creative role in the design and making of their own products (Mackrell & Pratt, 2017). When enacted in the context of AI, it typically manifests as robot-building, (but can also be observed in both unplugged and plugged programming activities). This may be due to the nature of AI, which can be novel and complex. In fact, Quieroz and colleagues (2020) sought to develop new methods of teaching AI to the general public (children included) to ensure the resulting knowledge is deeper and more reflective of true AI principles. To demonstrate AI principles, students may benefit most from engaging in constructionist activities in which they have the opportunity to become creators and producers of AI, rather than simply consuming the content. The act of making allows an abstract concept to become visible. However, as Alimsis and Kynigos (2009) note, constructionism in the context of making and programming in K-12 education can often be limited (there is often a plateau when robotics programs are not truly open-ended). This can present challenges as many educational robots have a "finish line" or goal. Therefore, it is recommended to select open-ended constructionist projects that often have updates to provide users with more opportunities. One example of this, noted in Alimsis and Kynigos (2009) is the case of Pico-crickets: an expansion was added in attempts to create more possibilities for creation and exploration, as well as to hopefully increase the interest of girls through allowing open-ended problem-solving and inquiry that may spark personal passions.

Preparing students for entering a world in which robots and intelligent physical machines permeate almost every aspect of daily life is an increasingly urgent educational goal. Martinez-Tenor and colleagues (2019) were interested in using Lego Mindstorms robots, a platform the authors note is both complex and engaging, to teach machine learning concepts to bridge the gap between theory and practice in robotics and reinforcement learning (and by extension, AI). By allowing students to build their own "cognitive robots", students were able to develop a personal educational experience while also gaining essential hands-on skills. In an open-answer question on post-surveys, students responded that the programming of a "real robot" was a motivating factor and the autonomous learning opportunities the course offered were engaging (p. 301). Moreover, students experienced an overall increase in performance on exams four and five (which were taken during their participation in Lego robotics) over exam three (non-Lego year) on the same AI topic (reinforcement learning). The constructionist approach to building robots engages situated cognitive learning processes in which students are required to build their own knowledge.

Project MLeXAI (Machine Learning eXperiences in AI) seeks to build a curriculum for teaching AI principles and major concepts through developing games. This differs from gamification or game-based learning as the students are using active learning processes for making. Similar to how the act of teaching robotics differs from teaching with robots (Alimisis & Kynigos, 2009), teaching game-building differs from teaching with games. Using Project MLeXAI, Wallace and colleagues (2021) endeavoured to increase student interest in machine learning by allowing them to engage in game-building. Wallace and colleagues explored the gamification of AI concepts through two different projects developed for the Project MLeXAI curriculum and compared student learning to non-game-based projects. According to the authors, games are a good choice for learning because they are visible in nature, which is valuable when dealing with the abstract principles of AI because both students and teachers can see student thinking, which allows students to adjust their processes as needed. Similarly, games often have an inherent scoring system that can be used for formative assessment and feedback. This comparison of game-projects and non-game has been emulated before (Bayliss, 2007; Parker & Becker, 2003*);* however, this is a relatively novel contribution to the field of AI literacy. Although there is an element of game-playing, the structure of the course was inherently constructionist. In the first project, students completed a series of assignments based on the game, Robot Defense. Using Java, students designed and implemented an AI interface or extended an AI concept used in the game. In the second project, students built digital checkers games. Instructors' observations of the students during the course noted that they were engaged, positive, and enjoyed their learning, and students self-reported similar findings in post-surveys, with students noting the projects were interesting and also had real-world applications. These findings differed little from the non-game projects group, however, the authors do not specify the exact method of instruction nor what the projects this group was given. The students in the non-game projects group also report high levels of interest, and it would be valuable to see whether the projects were constructionist (yet not game-based) in nature, and whether this influenced student enjoyment and learning. Despite this, the study suggests that a constructionist framework, particularly game-building, due to its ability to make student thinking visible and its active learning component, makes a good choice when developing students' technical AI skills.

Video games have become embedded in modern society for almost 40 years. Gamification has been demonstrated both in scholarly research and education AI challenges. Gamification is the inclusion of game elements in non-game contexts, such as education settings. Elements of gamification in the classroom include point systems, teams, missions, and goals (Fulton, 2019). Similarly, game-based learning is an educational opportunity through means of a game, physical or digital. Games were once thought to be strictly for entertainment purposes, but educational games have been noted to be effective conduits to learning outcomes (Chubarkova et al., 2016). In the past few years, games have been developed and released specifically to enhance and support students' computational thinking. There are often game elements infused into introductory AI and computer science courses (Vahldick et al., 2014) while games are often used to test AI methods by developers (Yannakakis & Togelius, 2018). There is a long history between games and AI that is both meaningful and engaging for students when developing competence in AI.

These two strategies, gamification and game-based learning, which hold similarities but are disparate methods, seem to be favoured in many contemporary education practices, perhaps because games are an appealing and present force for many children (Giannakos et al., 2021). It is important to acknowledge that the strategy of gamification differs from those of game-based learning. Gamification seeks to incorporate principles of gaming to motivate and encourage learners to participate in learning through the use of leaderboards, point-reward systems, and badges. On the other hand, game-based learning embeds game-like experiences into the learning activity itself (University of Waterloo, n.d.). Applying these approaches to complex subjects like AI can, conceivably, increase student motivation and increase enjoyment. Moreover, perhaps game-based learning (specifically digital game-based learning) is a popular choice increasing AI literacy because many digital games use AI interfaces (Konen, 2019) and in the realm of game development, AI games can often be programmed to teach and refine themselves, leaving a lighter load for students in computer science who cannot realistically spend time in AI development and game development.

2.3.4 Game-Based Learning for AIL

Game-based learning has been widely regarded as a motivator for student learning (Erhel & Jamet, 2013; principles in AI learning is a study by Sakulkueakulsuk et al (2018). Sakulkueakulsuk and colleagues investigated gamification as a means of teaching machine learning (ML) concepts, specifically classification. Eighty-four Thai students in grades 7 to 9 participated in the 3-day digital game-based workshop. The workshop specifically focused on classification and used mangoes – a popular fruit in Thailand – as a theme upon which they built ML datasets prior to training algorithms. The workshop was divided into three phases, the first of which focused on mangoes and their sweetness. “Sweetness” served as the property for constructing datasets and was determined via colour (Green mangoes were categorized as unripe and yellow categorized as ripe). In phase two, students were tasked with adding an additional category of quality (Grade A, B, or C). Each time the algorithm correctly categorized the mangoes based on quality; 50 points were earned. The third and final workshop had a more explicit game-based focusing and integrated the application of machine learning to real-world contexts (in this particular case: agricultural practices). Researchers employed a "marketplace" structure in which students auctioned mangoes using their trained algorithm to select sweet mangoes. Students were given a budget of $1000, with additional amounts for their accumulated scores from phases one and two. Students reported higher levels of engagement and hands-on interactivity than in their traditional classroom setting, where AI is not a topic of discussion. Despite the students' middle school status, the scores collected from the three phases demonstrate that AI concepts are not only possible to learn prior to high school, but are also, with the correct methods, engaging and motivating. Similarly, students detailed more confidence in both interdisciplinary thinking (computer science and agriculture) and futuristic/innovative thinking. This study is a good example of an effective model to learn the technical skills underpinning AI, such as machine learning and programming, while also stressing real-world applications. To combat stereotypes surrounding AI, it may be important to foster an understanding that AI goes beyond media depictions and has both relevant and useful uses in society's sectors.

As reported earlier, Choi and Park (2021) purport that those who understand and develop AI will wield power in future societies. This is a salient point that illustrates the current value of AI literacy. By this statement, one can infer that if students are not AI literate as adults, they will be functionally disadvantaged in our world's near-future landscape. Choi and Park (2012) explored how gamification, a strategy often regarded as capturing student interest and motivation, can be leveraged to teach essential AI concepts. The authors note that AI concepts, at their most simple, are still relatively complex. This perhaps leads to teachers omitting or de-emphasizing the topic of AI in classrooms, despite its relevance as a global issue. Using the AI4K12 framework, the authors developed an AI curriculum (with the ultimate goal of gaining an understanding of Convolutional Neural Networks, or CNNs, using the popular theme of board games). The authors designed an unplugged board game that simulates the concept of CNNs. The student who collected the most characters and typical characteristics on the board is deemed the winner. As students played through the game, scaffolded sub-tasks were added that increased complexity for comprehensive learning. For instance, after the game was played, students moved onto a subtask, which involved verbalizing the AI principles involved in the game. If students demonstrate accuracy, they are awarded points. These gamification concepts were then applied to the course as a whole, and a gamified teaching method was developed. This included using challenge-based problems, setting goals, completing quests, and storytelling. This AI curriculum was then implemented in a school setting, with 152 participating students (152). At the conclusion of the curriculum, students responded using a 5-point Likert scale and were asked about interest (content, participation, expectations, what they hope to study in higher education) and understanding (AI, CNNs). Students had significantly high levels of both understanding and satisfaction, suggesting that perhaps gamifying AI principles is one key to unlocking student interest, motivation, and understanding. Wallace and colleagues (2010) note that this motivation may stem from the pre-existing interest that students have in games. In fact, Leutenegger (2006) reported students often surpassed course expectations and project requirements in his game-based computer science courses. This can be attributed, perhaps, to the enjoyment and motivation students have in both playing and building games.

Similarly, Chubarkova and colleagues (2016) designed a game-based learning module for college-level computer science students to investigate AI. The authors designed a game using Unity, a popular cross-platform game engine. The game design was relatively simple: a 2D side-scroller in which players interact with various objects and locations. Within the game, students read theoretical material on AI concepts and principles and were given a short test. If students passed the test, they were able to progress to secret areas with additional content that students were then tested on. At the end of these secret locations, the characters levelled up. Each level was designed to slowly increase in difficulty. The authors note that this increases emotional stakes and ultimately satisfaction when challenges are overcome. Interestingly, the authors found that when comparing final test scores (for AI courses) for groups in the computer science program, those who were in the experimental game-based learning group had the highest test results. From this study, one can draw the conclusion that digital game-based learning techniques are effective for increasing student learning outcomes in AI units, especially when there is a perception of a challenge that has been overcome and emotional stakes are involved. This is something echoed by neuroscientist Daniella Kaufer, who notes that both active learning and moderate stress are benefactors to the learning process (Kaufer, 2011). However, it is unclear whether a similar game structure would lend itself to an elementary classroom when students are younger and perhaps have not developed as sophisticated socioemotional learning skills or stress-related coping skills.

2.4 The Social and Ethical Dimensions of Artificial Intelligence in Education

The social and ethical dimension of critical thinking for AI literacy is scarce in the literature. Even so, Skirpan et al. (2018) assert that ethics is a necessary component of teaching AI in graduate and undergraduate courses. However, learning about the ethical and social dimensions of AI are not valuable only to future developers, programmers, and technologists, because even if students do not advance into computer science careers, every student will certainly interact with AI daily.

Many AI algorithms that exist currently are touted as being "objective," and many believe this. However, there is ample evidence that algorithms can and often are programmed with bias against people of colour, those in lower socioeconomic statuses, and women (Ali et al., 2019), and these algorithmic biases are one of the most pressing concerns in AI (Green, 2018). These biases may take the form of not recognizing certain accents, skin tones, not recognizing certain hair types or head coverings, and having a lower recognition threshold for certain facial features (Green, 2018; Buolamwini & Gebru, 2018; Roselli et al., 2019). Ali and colleagues (2019) developed an Ethics + AI Curriculum, the AI curriculum to have an explicit and main focus of ethics, to address the gap between ethics and usage. The authors justify their targeting of middle school students by citing Kohlberg's Theory of Moral Development (Kohlberg & Hersh, 1977), which posits that children between 8-13 years old begin to develop the capacity to reason about authority, social order, and reciprocity. Interestingly, the authors chose a constructionist framework to enact their curriculum and used PopBots to explore the ethics of AI in three scaffolded lessons on topics like datasets, supervised machine learning, and algorithmic bias. The first lesson introduces AI, datasets, supervised machine learning, and the notion of algorithmic bias.

A singular framework in which ethics is explicitly addressed is not sufficient. In a review of AI programs and frameworks conducted by Zhou and colleagues (2020), it was noted that only 13 of the 49 programs and frameworks reviewed purposefully addressed ethics. Despite appearing as one of Touretzky et al.'s "big ideas" and also a leading principle in the Canada Learning Coding framework, a focus on ethics is largely excluded from pedagogical narratives when teaching AI. Focusing only on technical skills, like algorithmic understanding and machine learning does not meet the needs of our modern landscape nor does it prepare students to critically and safely engage with AI.

2.5 Youth Perceptions of Artificial Intelligence

Though literature surrounding this topic is rare, it is imperative to include in order to develop a potential map of how students conceptualize AI. It is difficult to develop critical thinking without understanding students' baseline understanding and perception of AI and robots. It is important to understand children's perceptions of AI to better address misconceptions and to discover any gaps in knowledge and thinking. Previous research has demonstrated that meaningful exposure to robots and artificial intelligence increases the complexity of children's opinions and perceptions surrounding AI and that having meaningful interactions with AI can help broaden the scope of what they consider to be AI (Williams et al., 2019; Bernstein & Crowley, 2008; Kahn, Friedman, Perez-Granados, & Freier, 2004). Bernstein and Crowley (2008) examined children's personal beliefs about robots to examine the impact growing up in a world populated by AI and smart devices has on children's cognitive development. The researchers found that experience (that is, opportunity to come to "know" robots) is key is transforming children's perceptions and criteria about robots and their intelligence and "aliveness". Moreover, children who view robots as to explore student perceptions of robots, researchers at the MIT Media Lab developed a novel AI platform, PopBots (Wiliams et al., 2019). This platform is primarily targeted at early childhood, as these students will grow up immersed in a world of AI. The purpose of the study was twofold: the first objective was to uncover how developmental factors impact children's levels of AI learning, and the second objective was to examine how children's perceptions of AI and robots evolved after participating in a series of AI-related activities. The AI curriculum was based on three concepts: knowledge-based systems, supervised machine learning and generative AI. No former research on children's capabilities to understand these concepts had been conducted at the time. In these different learning modules, students trained the robot to interact in different ways. For instance, the first module had students train the AI to play rock-paper-scissors. This is different from what students were expected to do in the supervised machine learning module, which focuses on classification. The second module, supervised learning, focused on teaching the machine learning model how to assess and classify healthy and unhealthy foods based on a set of pre-programmed information. The third module on the topic of AI was focused on generative AI and demonstrated how music can be generated by AI depending on the desired "mood". This is an important piece of the narrative because generative AI and music construction emphasize the potential for creativity in machines through constructionism and how both students and student-constructed AIs can become producers of content. After students worked through the modules, they were given a series of questions presented in the form of questionnaires on the topic of AI understanding (within the confines of the three topics mentioned prior), a questionnaire on perceptions of robots, and a Theory of Mind assessment. Theory of mind is a mental mechanism that allows for humans to distinguish their own thoughts and feelings from another's (Frith & Frith, 2005). Participating students seemed to grasp AI concepts well, with the highest performance seen on the Knowledge-Based Systems questionnaire and kindergarten students out-performed pre-K students in terms of understanding. On the perceptions questionnaire, most children reported that they believed robots can learn (a target response) but also reported that robots always follow rules without exception. This may have interesting implications for future studies. Most students were unsure whether AI is smarter than themselves.

Similarly, a study examining student perceptions of Robovie, a humanoid robot, found that most children (90 children aged 9, 12, and 15) believed that Robovie was intelligent, had mental states, and could both feel and display different emotions after a prolonged period of time interacting with it (Kahn et al., 2012). The interactions with Robovie were unique in that each session of interaction was prefaced as playing a game with Robovie before being "interrupted" by an experimenter who put Robovie into a closet, despite Robovie's wishes not to go away. The participating children cited that they believed Robovie was a social being that could comfort and be comforted, be befriended, and be trusted. One child said of Robovie, "I feel like Robovie can have expectations of something which [if] it doesn't get its way it can feel like it's slightly unfulfilled or less than it could be, and I feel like that's part of what sadness is" (p. 309). Robovie seemed to help children contextualize and objectively examine emotions, while recognizing that the internal processes of a robot may be different from their own human processes. The students deemed Robovie worthy of trust, and although Robovie may have been a trustworthy AI, parallels can be drawn towards the trust of Robovie and other technologies, like websites and phones. Further research may want to shed light on the spectrum of personification and trust. For instance, would children rate apps that use characters high in trust like they did Robovie? These perceptions can be important as humanoid and personified AI machines become more common. It is significant to develop learning environments in which students can gain deeper understandings of robotics and AI and the moral standing of such machines, as well as how to critically determine what program is to be trusted or not.

Druga and Ko (2021) sought to investigate how children's perceptions of AI are modulated when engaged in technical tasks such as coding "smart programs". The authors describe AI literacy as "the ability to critically decide if, when, and how to use smart devices" (p. 2), so although it differs from the definition prescribed in the current thesis, the authors are interested in the shifts in perceptions surrounding critical AI use as a result of tasks modulated by situated cognition, in this case, coding.

2.6 Inequity in Artificial Intelligence Fields

Research has identified culturally entrenched gender-based stereotypes as a threat to * interest in science, technology, engineering, and math (STEM). Children often go through a socialization process which includes steering the child's interactions, interests, and overall upbringing based on a child's assigned sex at birth. These sex norms are evinced in activities and toys marketed to one sex which have been embedded in Western society. STEM-based toys that feature engineering, mathematics, and science, are often designed and packaged in a way that would appeal to the "typical" boy according to traditional societal expectations. Conversely, fashion, dolls, and animal toys are often designed to be marketed to girls. These gender norms can manifest as cultural stereotypes, which perpetuate the idea that STEM is mostly for boys. The stereotype threat (Deux & Lafrance, 1998) continues to perpetuate in everyday society. This streamlining of interest based on sex perpetuates a stereotype that positions STEM as something boys are naturally inclined toward (McGuire et al, 2020). Similarly, the stereotypical scientist to most children is not a woman (Miller, Nolla, Eagly, & Uttal, 2018). Representations of scientists in the media have long since been older, white males, similar to the mad scientist that may look akin to Einstein. Though some may believe that media and stereotypes have no bearing on the course of human action, Cheryan et al., (2013) conducted a study that revealed how media representations can act as a barrier into STEM and significantly influence individuals' identities. The authors concluded, through a series of interviews and surveys with college students, that stereotypes limit women's interest in STEM, as the strong association with men inhibits the ability to see STEM as a realistic option. Moreover, when considering a post-secondary path to pursue, students often compare themselves to those in the field and whether they would succeed in the environment. An earlier study by Cheryan et al., (2011), demonstrated that undergraduate women were less likely to be interested in taking computer science if exposed to a computer science classroom with stereotypical male objects and decorations (video games and Star Trek memorabilia) than those exposed to a classroom which did not contain these objects. Though many girls and women do enjoy video games and typically masculine- associated media, the presentation of stereotypes may signal that there is less "room" for girls in the field. These stereotypical portrayals and media representations have the power to influence the way in which people perceive the world as they establish norms and barriers that limit STEM as a perceived option for girls, perpetuating the misconception that boys/men are simply better suited to STEM. This results in a stereotype and the inability to create a lasting STEM identity for girls. A STEM identity can be defined as, "a young person coming to see both her current and possible future selves in STEM" (Kang, 2018).

As Ceci, Williams, and Barnett (2009) found, there still remains a greater gender gap in girls entering the STEM pipeline in post-secondary education than would be predicted by ability in STEM subjects. Krishnamurthi, Ballard, and Noam (2014) assert that many young individuals have a lack of STEM "identity", meaning that they do not see themselves in the prototypical scientist, despite often holding positive feelings of science. Their evaluation of outside-school-time (OST) STEM programs identified qualities that may support bridging the gap between STEM engagement and identity. The evaluative data supports the idea that participation in out-of-school programs allows students to foster curiosity and interest in STEM and gain proficiency, thus elevating participant STEM identities. OST programs build a relationship between the student and STEM, allowing the student to perceive STEM as part of their identity. On a similar note, Halverson (2015), writes about how personal narratives (or, identities) are embedded and influence public perception of narrative and influence community voice. In this article, Halverson uses a continuum of reportability (uniqueness) and credibility (normalness) to examine how personalized narratives are transformed from reportable to credible. According to Halverson, when a personal narrative is examined within the context of community and is presented through performance, it undergoes a process of actualization and can become more credible through normalization. Halverson describes the process: "These narratives begin with highly reportable individual stories that become more credible community narratives of experiences as they are adapted into scripted scenes by the performance community." (2015). Constructing a personal narrative for public performance allows marginalized groups to construct representations of themselves in the world around them, creating a more actualized identity. Halverson's work deals primarily with members of LBTQ2S+ communities with highly reportable narratives, that is, their personal narratives are seen as unique. Sfard and Prusak (2005) posit that collective discourses affect personal narratives, and these narratives are then combined into a community voice. These ideas of the interrelation between public and personal identities harken back to the glaring gap in media representations and the lack of women's narratives in STEM. Applying the framework outlined by Halverson, an assumption can be made that perhaps many women may see their personal STEM identity as less "actualized" as there are fewer instances for normalization in the community, hindering women from achieving a viable STEM identity. Similarly, using Halverson's continuum, the personal narrative of a woman in STEM is high in reportability and low in credibility, thus influencing public perception of who a typical scientist is, further limiting the capacity to achieve a viable STEM identity. In a society that has an acute lack of collective discourse surrounding women in STEM, it affects personal narratives of women, in turn affecting the voice of the community or public (resulting in a cycle that prevents women from attaining a viable social identity in STEM). Halverson (2015) also notes that adolescence is a time when youths are actively searching for a viable social identity through "trying out" different selves. As adolescent individuals try out potentially viable identities, they also eliminate identities not seen as viable. Using this article and other sources cited above, it can be inferred that girls should be encouraged and supported in their adolescent years to ensure that there are more opportunities to "try out" a STEM identity. After school programs can be a facilitator of this identity. Representing women in the STEM classroom and supporting girls' participation has the potential to increase girls' motivation to pursue STEM careers.

The gender gap in STEM is a long-standing issue across the globe in which women are underrepresented in higher education STEM programs and STEM careers. The gender gap is a critical issue when considering girls and their perceptions of and relationships with AI. A number of factors have been put forward as possible mitigators for girls entering STEM. For instance, the "Breadth Model of Female Underrepresentation" posits that girls typically have strong quantitative reasoning skills and verbal/communication skills, allowing their pool of appealing potential careers to be wider, compared to boys, who typically have strong quantitative reasoning skills, yet typically perform lower than girls when considering verbal/communication skills (Valla and Ceci, 2014). Other research posits that women may have lower self-perceptions and confidence in the context of STEM aptitude (English, Hudson, & Dawes, 2011; Catsambis, 1994). The preponderant influence in AI's directional development currently rests in the hands of men, with women comprising only 19% of graduates from computer science undergraduate programs (Wang & Degol, 2016). This is important because students often compare themselves to those already in a field in order to assess whether they would succeed in the environment. An earlier study by Cheryan et al., (2011), uncovered that undergraduate women were less likely to take a computer science program if exposed to a computer science classroom in which stereotypical masculine interests (e.g., Star Trek decorations) were displayed compared to women who were exposed to a classroom without these decorations. Though many girls and women do enjoy video games, the presentation of stereotypical male interests may signal that there is less "room" for girls in the field. Stereotypes are able to influence the way in which we perceive society and the world and continue to perpetuate misconceptions surrounding women and STEM.

2.6.1 Role Models

Technovation is an organization dedicated to empowering women and marginalized people in tech and computer science through outreach programs. One such program that Technovation offers is Technovation Girls. Technovation Girls aims to help bridge the gap between girls, AI, and computer science at large (technovation.org, n.d.). Annually, Technovation holds a program in which girls ages 10-18 work in teams and are joined by a mentor to code applications that solve a real-world target problem. Technovation reports that participating girls communicate more interest in both technology and leadership post-program. Further, 58% of participating girls go on to enroll in further computer science/tech-based programs and camps. The exact factors that contribute to the large success of this program cannot be summarized with certainty. However, the open-ended constructionist environment, along with access to role models and mentors may play a role. In fact, role models have been identified as a very important factor in supporting girls in STEM (Stoeger et al, 2012; Broadley, 2015; Skipper & de Cavalho, 2019; Tyler-Wood et al, 2012). Broadley (2015) found that pairing students with role models who are both enthusiastic and successful in STEM can help combat the lack of perceived diversity in the field. According to Broadley (2015), women mentors and role models may also help young girls see that STEM is heavily linked to helping others and benefiting society, a characteristic that girls have traditionally valued when considering future careers. Broadley also mentions that role models should be relatable and engaging to promote interest and help girls build their STEM identity by demonstrating the merits of STEM and its potential as a viable career choice. This suggests that perhaps it is best to develop AI programs targeted specifically to girls and the potential positive impacts AI can have on society if developed and used responsibly.

In a 2013 study by Stoeger, girls ages 11-18 participated in a one-year personal mentoring program in an online environment (E-Mentoring). Stoeger (2013) discusses the complexities that contribute to limitations for female STEM participation and identifies three main causal networks: stereotype threat, which includes foundational issues of social influences (including gender-based division of labour in Western societies), the interests and individual goals of individuals, and finally, subjective action spaces which are composed of opportunities (or lack thereof) and barriers due to stereotype threat and substandard implementation of STEM activities. Perhaps providing girls with a role model or mentor has the potential to act as an effective intervention in STEM, as girls are given the opportunity to view actual instances of women excelling in STEM, something they may have had limited exposure to in the past.

On the same note, Tyler-Wood et al. (2012) also stress the impact of women-led STEM mentorship for girls in their studies. They conducted a three-year study that examined the role of mentorship by women. Bringing Up Girls in Science (BUGS) is a mentorship program for 4th and 5th grade girls. Though the study lasted 3 years, only the first year of data was selected for analysis due to the girls in the group being on the cusp of entering college or in the process of selecting a major and attending Texas Academy for Mathematics and Science (TAMS). Other mentors were from the American Association of University Women. The mentors were matched with the BUGS participants. The mentors and the participants had approximately 120 minutes of face-to-face interaction a week for the academic year and kept in regular contact through email, phone calls, and a platform developed for the program. The study also included a control group that did not receive any support. Using pre- and post-surveys, participants answered questions based on basic knowledge of science (Iowa Test of Basic Skills – Science, ITB-S). Interestingly, this study examined how BUGS influenced both the mentors *and* the participants. Upon completion of the analysis, the BUGS participants made significantly higher gains on the ITB-S, indicating that the BUGS program did have a short-term positive effect on science-based skills and knowledge. To investigate the long-term impact, a follow up study was conducted in which 14 former BUGS participants were surveyed and compared to contrast groups. At the time of the follow up, these original participants had completed high school and were entering or had entered college. This is significant as the long-term impact of the BUGS program was able to be assessed. Results showed higher scores in perceptions of science for BUGS participants. Therefore, this study suggests that the role of the mentor is a significant factor of success in science-based knowledge. The lack of access to role models and mentors in AI, tech, and computer science, may contribute to the lower rates of interest in girls.

Kang (2018) has produced a large body of work that has been developed with the aim of identifying (binary) gender barriers in STEM and effective methods of overcoming them. Kang suggests that girls of colour may not feel fully welcomed into the STEM community, and may not be acknowledged for their contributions, talents, or potential in STEM subjects. The authors deemed it crucial to explore STEM-related experiences in multiple contexts (e.g., home, after-school, school science classrooms) and how these multiple contexts impact the development of STEM identities. Using the lens of an identity gap, rather than a gender gap, Kang (2018) posits that the underrepresentation and the gender gap of participation in STEM is due to girls of colour being unable to see themselves in STEM, therefore eliminating STEM as a viable career option. After all, a career choice, including STEM careers, is in part due to a self-evaluated notion of identity. Eisenhart and Finkel (1998) assert that science as a cultural practice has been constructed by the biases, ideas, and experiences of white men. Many women, then, gravitate toward fields of science that are more in line with values that girls are taught from a young age, like caring for people and animals. This can explain a large number of women in health and biological sciences compared to the number of women in engineering. To further analyze this issue, Kang et al.,

(2018) investigated how girls of colour build STEM identities through analyses of a large data set (n= 1821) consisting of girls of colour from economically disadvantaged communities in five American states. The study was a contribution to a larger project examining adolescent girls' participation and engagement in after-school science programs and the impact on the development of identity. Through surveys, girls of colour responded to STEM-related questions that required responders to position themselves in relation to STEM as a field and a possible career choice (e.g., "I am not at all good at science"). The theoretical model constructed in this study used both Identity Constructs of Current Self and Future Self. Within current self, the identity constructs examined were: Personal and family backgrounds (variables: sex, ethnicity, parents' college attendance, parents' having a science-related job, family science orientation), participation in science-related activities (variables: at home, at out-of-school settings, in-school settings), and perceptions (variables: self in and with science, and science and scientists' work). Within Future Self, the identity construct examined was possible future selves in STEM (variables: Biological sciences – basic and applied, and physical sciences – basic and applied). This study identified that the strongest predictor of STEM identity (in the context of pursuing a STEM-related career) was self-perception. From this study, it is evident that a sense of self in relation to STEM is the strongest predictor of interest in STEM. This finding further propels the notion that building a viable identity in STEM, particularly for individuals in marginalized groups, is crucial.

The international nature of the publications above speaks to how AIL is an urgent and global issue. The gap in knowledge that exists between the use of AI and the understanding of AI is a worldwide issue. Burgsteiner et al. (2016) note, "Many of us know about the existence of services and devices based on AI, but hardly anybody knows about the technology behind them" (p. 1), further stating, "Currently, computer science education in school does not focus on teaching these fundamental topics in an adequate manner" (p. 1). There is a need (and seemingly a growing demand to match) for a more holistic approach to teaching AI, one that is not simply focused on Turing tests or neural networks, but instead, integrates theoretical perspectives and practical skills to provide meaningful opportunities for student critical thinking to develop. Moreover, due to the abstract conceptual nature of AI principles, gamification and frameworks that support hands-on knowledge-building like constructionism, prove to be an important way to represent AI concretely. Similarly, game-based learning and gamification allow for advantages like making the learning process visible, rewarding small tasks (with points, trophies, or advancements), the opportunity to customize learning, and increasing autonomy as a learner, as games are primarily individual (not team-based), and positive reception by students (Vahdick et al. 2014; Wallace et al. 2010).

2.7 Gaps in the Literature

There are prominent gaps in the literature that this thesis works to address. There seems to be a lack of research seeking unification between the two facets of AI literacy, both technical competency and critical thinking. An academic compartmentalization of each area of comprehensive AI literacy is the current norm, with most of the focus falling onto developing coding and robotics skills. Much of the literature is focused on developing coding and programming skills that will equip learners for 21st century societies and ready them for the workforce. To achieve true AI literacy, education must move beyond viewing AI as a prescriptive programming exercise, machine learning concepts, and technical competency, but as a broad topic that encompasses ethical and social issues and critical thinking skills. Further, there is a dearth of research conducted on the subjective "starting point" from which students learn about AI and how students view AI as a concept and a tool in their daily lives, and the ethical implications that arise from AI use. The goal for educational institutions is moving towards developing critical AI users in students, those who are able to objectively and critically think about how AI manifests in daily lives and interactions. However, the shift to highlight the ethical dimensions of AI use are slow-moving. The ways in which youth perceive and comprehend ethical implications of AI use are still largely unexplored. Research shows that some students can attribute emotions to humanoid robots (Kahn et al., 2012), but the understanding youths possess surrounding the daily implications of using AI are still unknown. The implicit (and explicit) beliefs that youth hold about AI, and how they use critical thinking to assess the ethical and social aspects of AI should be given considerable thought so that educators can design effective curricula and programming to bolster understanding of all facets of AI. Similarly, whether boys and girls hold similar or dissimilar views of AI have not been investigated in any found research. Girls, typically, are ushered away from STEM subjects from an early age (Broadley, 2015). Therefore, it may be feasible that girls have different perspectives of AI and the ethical implications of AI than boys do, potentially having been underexposed or less explicitly informed on the subject. Finally, an under-analyzed area of the literature review is the characteristics of AI programs and/or curricula that contribute to conceptions that youth hold and their shifts in thinking. It seems as though there has been much investigation surrounding the ways

AI is used as both a tool and a subject, but there is still much work to be done when one considers the starting line to achieve comprehensive (i.e., AI education that includes ethical considerations and critical thinking) artificial intelligence literacy and the role that gender plays in developing shifts in youths' thinking to a more balanced view of AI. Further, uncovering the ways in which youth conceive of AI can better inform programming to target realistic and effective AI education and may also reveal insights into mechanisms that promote development of AI literacy.

AI literacy proves to be a confounding subject in the research. Most authors and papers cite AI literacy as a critical educational matter, yet there are a limited number of studies that address this directly. However, this literature review reveals that AI literacy should be divided into two components: Technical skills and critical thinking. Moreover, there is largely a gap in the research in which the critical thinking component of AI literacy is all but left out. Despite the ubiquity of AI applications that support teachers' pedagogical instruction and management as well as student learning outcomes, there is demonstrably less relevant literature on the matter of how the ethics and social implications of AI are being taught to students. This notion holds particular salience as it illustrates the underpinnings of the problem: AI continues to secure more significant directional roles in classrooms and daily lives; however, the work to educate youth on how to critically question the development and use of AI does not yet match the speed of growth in classrooms the former is achieving. Left unaddressed, this may create a gap in knowledge in which the ethical implications and social impacts that AI will spur are missing. With that, new frameworks and curricula are being developed that include the social dimensions of AI, like AI4K12 and Canada

Learning Code. These frameworks are not yet in every school or classroom, but if widely adopted, can help bridge the gap between the ethical and the technical.

2.8 Research Questions

The literature review revealed emerging trends in AI for the classroom as well as gaps in the literature. From these considerations, research questions were developed with respect to the camp's development, goals, and participants. The questions that the current research addresses include:

1. a) What are the shifts in thinking (pertaining to artificial intelligence and critical thinking) that occurred in participants as a result of the camp?
2. What design elements of the camp contributed to the shifts in thinking of participants?

Chapter 3

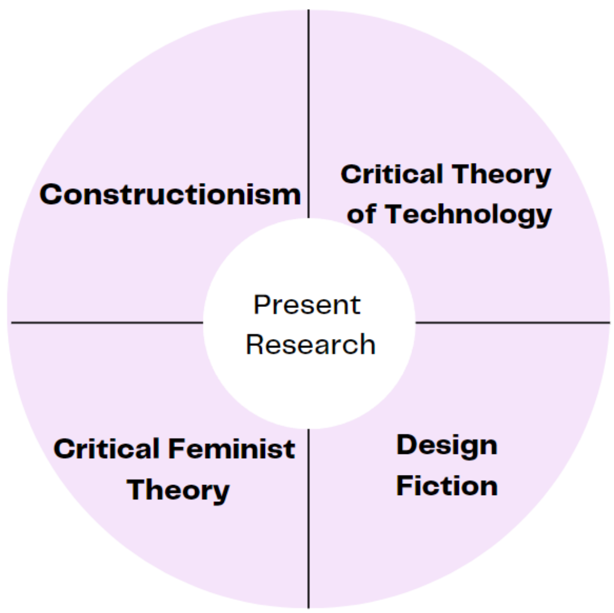
Theoretical Framing

3.1 Overview

This chapter will provide the theoretical background and context to the research. Four theoretical frameworks have been used to inform the current research. This means that the data and conclusions drawn are examined with particular lenses that allow the data to be given meaning. Integrating theoretical frameworks in research is foundational to constructing knowledge and linking new knowledge to pre-established knowledge and has even been likened as the "blueprint for a house" (Grant & Osanloo, 2014, p. 14). The theoretical frameworks that have been used to both develop the research and understand the research are constructionism, feminist theory, and critical theory of technology. Theoretical frameworks provide the researcher more focused methods of analyzing, synthesizing, and experimenting and acts as a guide to build the methodology and modes of analysis. Mertens (1993) asserts that theoretical framing significantly affects each and every step in the research process, and it is for this reason, theoretical frameworks should be selected early in the process of developing a research goal. Once this process concludes, a conceptual framework can be constructed using the theoretical framework as foundation; this is why theoretical framing is imperative to the research process – without it, all subsequent work lacks the pillars or structure grounded in documented and existing explanations for the targeted phenomena. subsequent sections, a more detailed description of each theory and how it relates to the current research is presented.

Figure 3.1

Positioning of theoretical frameworks to current research



3.2 Constructionism

Constructionism is a theoretical framework and practical approach to pedagogy that emphasizes active learning, situated cognition, and hands-on experiences. Constructionism informs this research through engaging campers through active learning processes that involve making, tinkering, and practices of situated cognition (Hutchinson et al., 2010). Papert (1990) was the first proponent of constructionism, using Piaget's previous theory of constructivism as a building block. Prior to the birth of constructionism, learning and education were largely approached with prescriptive, instructionist methods that aimed to induce learning in students through lectures, teacher strategies, and practice-based skill-building exercises (Jonassen, 1996). Instructionism sets the teacher as the focal point of the learning process, purporting that educational outcomes are enhanced by bettering teaching strategy (Cannings & Stager, 2003). With this in mind, it is clear why Papert (1990) introduced instructionism as a direct contrast to constructionism. Within the context of AI, instructionism is embodied in AI as a tool for teaching and learning – It is implemented with the goal of improving instruction to better improve student outcomes. Constructionism, conversely, can be summarized in the quote, "Constructivism is the idea that knowledge is something you build in your head. Constructionism reminds us that the best way to do that is to build something tangible – outside of your head – that is personally meaningful" (Papert,1990). Constructionist frameworks often de-emphasize the role of instructor and instead transform the role of teacher into something of a facilitator, rather than a director (Alimsis, 2012). One modern pedagogical approach often synonymous with constructionism is "making". Maker pedagogies are often branded as a rebirth of constructionism – However, the differences between the two are not clearly defined, and both constructionism and making seem to be used interchangeably (Alimisis & Kynigos, 2009). Constructionism and making seem to be a popular choice when teaching AI-related skills as a technical concept, especially when educational robotics is the targeted theme of the course (Alimisis, 2012). This is likely because robots are often a point of interest for students, and providing students with opportunities to gain hands-on experiences using robots is a way to ensure consistent motivation. Moreover, the act of building (i.e., making and tinkering) a robot is grounded in constructionism making it a natural fit for developing the applicable, hands-on skills needed for full AI literacy. In fact, Khan and Winters (2020), wrote, "Constructionism, long before it had its name, was intimately tied to AI" (p.1).

However, constructionism is not synonymous with physically making, building, and robotics. Digital making and technology use is a critical piece of constructionism (Papert, 1999), and some researchers often cite constructionism as framework of the future (Cannings & Stager, 2003). In fact, Turkle and Papert (1990) described the computer in terms of its potential use as a tool for universal learning and knowledge construction, writing: 'When we looked closely at programmers in action we saw formal and abstract approaches; but we also saw highly successful programmers in relationships with their material that are more reminiscent of a painter than a logician', before going on to write, "the diversity of approaches to programming suggests that equal access to even the most basic elements of computation requires accepting the validity of multiple ways of knowing and thinking, an epistemological pluralism'. Perhaps counterintuitively, the computer, digital artifacts, and programming, are not only compatible with the principles of constructionism, but computers can be used as tools to develop personal autonomy and construction of both abstract and concrete knowledge.

This constructionist framework is also utilized when attempting to rally public interest in AI. The AI Family Challenge, developed by Technovation in 2019, is upheld by maker pedagogies and constructionism without involving physical robotics (Technovation, 2019). The AI Family Challenge calls families to learn about AI and use AI principles to solve a challenge their community faces. The participating family enrolls in 10 AI lessons that provide the basics of AI and guide families through the design process of application building. In 2020, the world summit champions were a family from Kazakhstan that developed Help2Hear, an automated sign language-to-text bot. The application allows users to record a video of their signing which is then translated into text via a visual-recognition tool. This challenge allows students with a limited amount of AI knowledge into a "low floor, wide walls, high ceilings" model and relies heavily on digital tools and spaces to enact participants' designs.

Constructionism as a framework for AI is well-established (Burgsteiner et al., 2016; add citations; add citations). Burgsteiner and colleagues (2016) noted that explorations of AI are typically offered at post-secondary levels, leading to a lack of AI competencies in K-12 education. Moreover, the authors offer the critique that many school-level AI courses and approaches only focus on narrow aspects of AI, like the history of AI, chatbots, or neural networks. The curriculum currently lacks a holistic, integrated approach to teaching AI. The researchers implemented seven weekly AI teaching units, underpinned by the principles of constructionism. Nine students (grades 9-11) participated, eight of which were males and one of which was female. Constructionism was chosen as a framework to establish an environment in which students would play an active role in the learning process. The workshops stressed hands-on components, and activities ranged from unplugged programming to robot construction. The researchers used Russel and Norvig's (2009) fundamental topics for AI as workshop units. These include automata, intelligent agents, graphs and data structures, problem-solving by search, classic planning, and machine learning. Each topic was underpinned by practical projects with constructionist opportunities to engage in making, tinkering, and building. Results indicated that the workshop was successful in teaching participants about the target AI concepts and largely resulted in higher levels of AI literacy. AI is typically introduced and interacted with in classrooms as a branch of computer science. Constructionism allows for AI to be thought of as both theory and practice, lending itself to a more comprehensive approach to AI.

Constructionism has guided the work during this digital AI learning experience. In this regard, I attempted to include and design constructionist-based learning experiences that would also pose challenging and thought-provoking questions to promote critical thinking.

3.3 Critical Theory of Technology

Critical theories confront how communication in society is used to uphold oppressive systems. By challenging current communication paradigms, critical theories attempt to offer alternative methods of communication and to further positive social and societal shifts (Foss & Foss, 1989; Paynton & Hahn, 2021). Critical theory began with a group of German sociologists in the 1920s and 30s who referred to themselves as the Frankfurt School (Stanford Encyclopedia of Philosophy, 2005). The online Stanford Encyclopedia of Philosophy describes three criteria that guide a critical theory, first proposed by Horkheimer (recognized as the founder of Critical Theory).

Critical theory of technology is another avenue by which to enact critical theory, and stems from Frankfurt School Critical Theory and Science and Technology Studies (STS). It is primarily concerned with the potential threat to human agency posed by an influx of tech-integrated applications, resulting in a “technocratic society” that diminishes the autonomy of an individual (Felt et al., 2017, p.1). Loss of agency through technology may manifest itself in more subtle daily interactions with AI: algorithms that decide what you will or will not like on a streaming platform, videos that are hidden or amplified depending on your viewing history, . Those who develop these algorithms are, in part, gaining some control over an individual’s day-to-day life. The accumulation of control allows those who develop and regulate technology and AI technocratic power. Technocratic societies are not only built upon the foundations of those who develop and regulate technology, but also by electing technical experts (i.e., a specialist in non-political, technical affairs) into government positions, though what can be considered a technocratic government is largely unexplored within political science discourses (McDonnell & Valbruzzi, 2014). With the potential shift to technocracy (which can best be thought of as the change of government officials from “politicians to experts [in technology]”) comes novel issues concerning the level of preparedness and competency those experts hold with respect to governing nations (Moreover, if those in power are technological experts, and they are also embedded in developing and regulating our everyday interactions with artificial intelligence and technology, this may lead to a blurring of privacy, autonomy, and government overreach. If those who govern these domains are of a singular majority, then a technocratic society and government keeps systemic power in the hands of one group of people and cannot reflect the diversity of nations. This is not to say that politicians should not hold knowledge of AI – in fact, having a technologically-informed government and AI-savvy politicians is important to our functioning world. In fact, it is favourable that politicians have a responsible and ethical relationship with AI, especially right now, as it seeps into government and policy-making practices. König (2022) has this to say about the matter:

> Reducing social and political problems to an optimization task, first, tends to undermine the idea of an irreducible pluralism of political views and perspectives marked by at least some degree of public deliberation. The idea that one can base decisions on the processing of data by AI systems that find optimal solutions makes any pluralistic exchange and integration of different views unnecessary. AI in political decision making, second, also conflicts with a process of ongoing contestation that occurs vertically between society and decisionmakers: If one assumes that optimal solutions can be derived from actionable insights obtained from processing information, this removes the occasion to contest decision making (p. 5).

The issue of who should be at the forefront of AI development and regulation may not be in our politicians, governments, or one single group of people and presents some issues that are opposed the democratic process. AI literacy should be a democratized goal woven into all levels of society. As AI camp was designed with the underpinnings of ethical and social issues in artificial intelligence – that is, AI bias, hegemony of white males, opacity of development and regulations, and furthering equity in AI – critical theory, particularly critical theory of technology (which addresses technocratic societies and autonomy of the individual), informs the ways in which participants interact with and respond to camp content. As mentioned in previous sections, technology and AI is rarely taught with a critical perspective in modern classrooms.

3.4 Critical Feminist Theory

Critical feminist theory adds additional foundation to the underpinnings of the theoretical framework for this study. Critical feminist theory engages intersectional perspectives to explain and challenge societal inequities women experience (Ferguson, 2017). Explorations into artificial intelligence will bring inequity embedded in society and technology to the forefront as tech and AI sectors are built upon systemic inequities in society and perpetuate gender stereotypes. Not only are women underrepresented in the AI sector (thereby excluding first-person perspectives from women in AI development), but most virtual assistants also such as Siri and Alexa are feminine-presenting entities, which may serve to reinforce gender stereotypes that suggest women are primarily secretaries or assistants (Adams & Ní Loideáin, 2019). Feminist theory, though disparate frameworks, informs critical feminist theory. Feminist theory's cornerstone theoretical ideas relate to social, political, and systemic factors that enforce gender norms and women's status in patriarchal society, the oppression of women in society, and the inequitable power structures and embedded societal and institutional systems that serve males (Grant & Osanboo, 2014). The addition of the word "critical" in "critical feminist theory" reorients feminist theory in a direction that opposes these systems (Clark, 2007). Considering the prominent stakeholders and decision makers in technology and AI are predominantly one type of person paired with the systemic oppression of non-white males in North American society, feminist theory must be positioned in the theoretical framework when exploring AI, especially as it relates to youth, who may not hold developed ideas or understandings of AI's place in both society and their micro-level daily lives. As Foss and Foss (1989) wrote,

> One way in which the feminist perspective challenges the existing research framework is by considering women's perceptions, meanings, and experiences as appropriate and important for data analyses. Rather than generalizing from men to create an experience for both men and women...(p. 67).

Although participants are youths, critical feminist theory can be applied to the camp as a broader contextualization of the differences that may occur between boys and girls and their experiences in a STEM-based AI camp. Judy Wajcman writes the following in *Technofeminism* (2009): "Studying technology from a gender perspective implies stressing how technological artefacts are designed and shaped by gender relations through their uses and meanings, there-by perpetuating differences and relations of power" (p. 108).

3.5 Design Fiction

The concept of design fiction has been around perhaps as long as humans have been able to conceive of the future, but has accrued special attention in recent years as a method, exercise, and framework for exploring potential and imaginative futures, also called speculative futures (Dunne & Raby, 2013), essentially posing "what-if" scenarios through narrative story-telling or world-building exercises. There is still some ambiguity surrounding the exact definition and the way design fiction can be leveraged in research (Coulton et al., 2017). Much like AI, design fiction takes on different roles and definitions depending on who is wielding it. In the recent past, design fiction has seen its place in company boardrooms as a way to learn from science fiction, to draw inspiration from the parallels in story and reality and past and future to create innovative and creative products (Graham, 2020). Bleeker (2009, p.7) describes design fiction as such: "Design fiction is about creative provocation, raising questions, innovation, and exploration." Often associated with science fiction, it has more recently been utilized as tool for exploring ideas, solving problems, and investigating alternatives to current social, political, economic, and ethical paradigms (Wakkary et al., 2013; Dunne & Raby, 2013). The role design fiction plays in youth education, specifically imagining and/or designing models to progress toward a more ethical and equitable future is limited. However, in 2017, Duggan and colleagues implemented an experimental design fiction-based research with 80 students aged 13-14, who employed a variety of techniques (discussion, comic strips, narrative-writing) and strategies to ideate future scenarios for their own school. The research never concluded as a myriad of ethical issues and loss of support from teachers eventually caused the project to dissolve. In another study, Maxwell and colleagues (2019) explored design fiction as a conduit to imagining more sustainable futures with elementary school children. The focus for this project was on bees and climate change, and participants drafted prototypes to help bees from the negative impacts of climate change, using maker technology such as 3D printing to create bee armour and specialized hives, among other innovative inventions, which had been developed over a series of design iterations (such as story-boarding, drama pieces, writing newspaper articles). The results were imaginative and innovative, and "the combination of design and drama complemented each other effectively in this project by reinforcing this sense of 'stepping out' their usual lived reality. This then enabled quite rapid and detailed learning about contemporary (and future) environmental issues" (p. 1493–1494). Design fiction has some very promising potential as a vessel for learning and imagining better futures; In the current research, *Meehaneeto*, a graphic novel including many elements of design fiction, will be used not as a tool for design, but a tool to support critical discussion. *Meehaneeto* will hopefully serve as a metaphorical backdrop to our own lives and society, but also encourage students to engage in their own internal design fiction processes, which may in turn transform their perspectives of AI and promote critical thinking around human-technology relationships. As Meehaneeto is science fiction in and of itself, it serves as a commentary for our own lives and the ways in which we use technology. Graham (2020) writes, "Indeed, a large part of the job of science-fiction writers is to explore the pros and cons of technologies, ideas, ways of doing things – and how they contribute to our future, and that of our planet." This is what *Meehaneeto*, and design fiction like *Meehaneeto* aim to do: To inspire, to encourage speculation, to consider past, present, and future technologies and the ways they have and can possibly shape our lives. Design fiction, though a budding topic of conversation in the educational landscape, is an extraordinarily powerful tool because it encourages individuals' to unabashedly follow lines of thinking, possibilities, and imagined scenarios to promote innovations and problem-solving. Framing a work of design fiction, such as *Meehaneeto* around critical conversations and ethical AI literacy is a promising conduit for developing critical thinking.

Chapter 4

Methodology & Methods

4.1 Overview

This chapter offers an overview of the design, methods, and analysis used in the research. For this research, qualitative methods of data collection and analysis were selected due to the open-ended and flexible nature of the camp. Over the five days, students were engaged in tasks and conversations that were best explored using qualitative research methods. The methods below hope to answer the following research questions:

1. What were the shifts in thinking that occurred over the course of the camp?
2. What were the design choices that supported or mitigated positive outcomes for campers?

The camp took place from July 19th to July 23rd, 2021, over Google Meet, due to health protocols surrounding COVID-19 safety restrictions limiting in-person gatherings. The following sections will provide a thorough outline of the specific research design choices, such as the type of research, research design, research tools, and methods of evaluation and analysis, and provide justification for them.

4.2 Research Design

The present project is exploratory qualitative research. This study was developed using thematic analyses with the support of case study methodology. Data collection methods included observations (of participant dynamics, interactions, and independent action), video recordings of consenting participants' actions, post-interviews with participants, participant Flipgrid data (participant-initiated video responses to a daily question), and these informed the development of the cases.

First, a thematic analysis was conducted using inductive coding approaches informed by Saldana's (2016) cyclical coding methods. I used a cyclical inductive coding approach to identify themes, resulting in a thematic analysis. Inductive coding was selected to prevent bias from forming within the interpretation of data and to mitigate the potential for finding passages of data that "fit" pre-determined codes. Instead, an inductive coding approach was used in which I identified a series of patterns from the data, and generated overarching themes within the context of the research using Saldana's cyclical coding approach. In this process, researchers begin analyzing data, performing their own meaning-making and interpretations and develop a set of patterns, or codes. After the first wave of coding, a second wave was conducted in which

The themes represent the internal processes that the campers' experienced and the tools or design elements that contributed to their evolution of thought. Creswell (2013) describes the process of qualitative analysis as such:

> One helpful way to see this process is to recognize it as working through multiple levels of abstraction, starting with the raw data and forming broader and broader categories. Recognizing the highly interrelated set of activities of data collection, analysis, and report writing, I intermingle these stages and find myself collecting data, analyzing another set of data, and beginning to write my report (p. 54).

After I generated overarching themes, I presented the general findings that fit within each theme. Then, I developed Stakian case studies reflective of each theme to offer more context about the events, experiences, and processes of a camper to offer more context of what may have spurred the shifts in thinking during the camp.

Stake argues that qualitative case studies are integral to understanding a particular phenomenon. However, the selection of cases is of great importance; he writes,

> A case study is expected to catch the complexity of a single case. A single leaf, even a single toothpick, has unique complexities-but rarely will be case enough to submit it to case study. We study a case when it itself is of very special interest. We look for the detail for interaction with its contexts. Case study is the study of the particularity and complexity of a single case, coming to understand its activity within important circumstances. (Stake, 1995, p. xi)

Case studies are used to describe and analyze highly contextualized situations while placing the situation within a broader context. The role of the researcher is emphasized in Stakian methodologies, and he states, “Standard qualitative design call for the persons most responsible for interpretations to be in the field, making observations, exercising subjective judgement, analyzing and synthesizing, all the while realizing their own consciousness" (p. 41). The researcher, in the case study, is also positioned as the interpreter, essentially interpreting the ways in which the subject is constructing knowledge or making sense of their surroundings and experiences. Stake (1995) further notes three distinct types of cases: intrinsic, instrumental, and collective, each with their own affordances in particular contexts. Collective case studies are used to gleam insight into a phenomenon or research question by compiling cases within a situated context. Therefore, in order to conduct an in-depth analysis of a participants' growth, Stakian collective case studies were utilized. Stakian methodology was further selected because Stake's epistemological perspectives are most similar to my own. Stake believes that knowledge is constructed rather than discovered and that there are multiple layers of truth to research - In other words, reality is subjective, and the researcher of a case study is an interpreter (Stake, 1995). The case studies are qualitative and interpretative; the researcher is an instrument in and of itself for analysis. This means that there will be bias and individual perspectives present in the research. The campers selected were based on my own interpretation of the overarching theme and those who best illustrated significant characteristics or markers of growth in each category, admitting the camper had robust data to draw from. As a result, the same participants are often re-presented as a case study within the context of more than one research question as a small group of select participants contributed much more often than others, despite encouragement, and therefore had much more rich data for analysis. The case study can be described as a "phenomenon of some sort occurring in a bounded context" (Miles & Huberman, 1994, p. 25). Case studies are a popular analytic tool in education

(Merriam, 2007). Wielding Stakian case study methodologies, In the process of any qualitative analysis, the researcher is the vessel through which information is dissected and communicated and the instrument for interpretation (Nowell et al., 2017). It is imperative to note that there will be some level of subjectivity present within data analysis, as in thematic analysis and Stakian case studies, the researcher is a vessel for interpretation, not pulling out pre-determined conclusions from the data, but analyzing the data through their own lens.

4.2.2 Camp Design

The first day of virtual camp began with a welcome and overview of the purpose of camp and the day. The first portion of day one was opened by welcoming campers and asking them their names, the kind of device they were using, and their favourite kind of technology. No campers answered the third question, perhaps because "favourite technology" was too ambiguous of a term. The students then completed a pre-survey that inquired into students' perceptions, attitudes, and experiences regarding: i) technology use; ii) coding and technologies; iii) perceptions of AI; iv) preferred ways to use technology for learning. The purpose of the survey was to gather an understanding of the students' technological skills and the depth or complexity of thought surrounding AI prior to the camp.

Breakout groups were pre-established based on consent forms. Students in the group that allowed audio and video data collection were in groups together, as were those who only consented to have audio data collected. During breakouts, the consenting group had their breakouts? recorded with audio and video which was subsequently transcribed. Facilitators met as a group after camp and participated in debriefs which were also used as a source of data. At the conclusion of each day, students recorded short reflections using Flipgrid in response to a posed question. Flipgrid is a digital tool used to record short videos. Unfortunately, the response rate for the Flipgrid activities was sparse. Finally, on the last day of camp, students participated in an interview that lasted approximately 10-15 minutes each. Students had the option to answer the interview questions on the mic or in the chatbox. The interviews re-visited many of the perception-based questions asked during the pre-survey to determine if shifts in thinking occurred and to identify the most cited sources of enjoyment during camp participation.

The camp was offered from July 19 to 23 2021, starting on Monday and concluding on Friday. AI Adventure Camp was advertised on multiple digital platforms, including the STEAM-3D Maker Lab website, Ontario Tech University's digital events calendar, and various other social media channels, such as Twitter and Instagram. The camp ran for approximately three hours per day, from 12:00 PM to 3:00 PM. The three-hour time constraint was selected to ensure students retained interest and did not become fatigued by being on a screen for too long. The camp had two camp facilitators, who took turns leading each day. For example, on day one, Facilitator 1 would lead the camp, and Facilitator 2 would provide program support (pasting links in chat, monitoring chat, supervising breakouts), and on day two the roles would be reversed. Additionally, two researchers were present at all times. During breakouts, each researcher would monitor a breakout room where a facilitator was also present.

The camp had an overarching focus on artificial intelligence and ethics. The camp was anchored to the graphic novel *Meehaneeto,* written by Janette Hughes and George Gadanidis, and illustrated by Ryan Terry. The plot of *Meehaneeto* focuses on a child and her mother who live in a world framed with dystopian or perhaps post-apocalyptic landscapes. The child and her mother wander this world, which is seemingly void of technology (referred to as "*Meehaneeto*"), with references to a time in the past when *Meehaneeto* were heavily integrated into society until a cataclysmic event. The daughter eventually discovers a flying scooter over the wall that separates humans from technology and re-introduces *Meehaneeto* into society. The graphic novel explores the themes of freedom, surveillance, data, AI, and ethics.

The camp days can be thought of as being divided into distinct halves: the first half of the day and the second half of the day. The halves were separated by a 15-minute break. The first half of the day had, in the beginning, been allocated one and a half hours at the start of camp. The first portion of the day (approximately 12:00pm to 1:15) was developed with the goal of providing participants with minds-on, supplemental activities, and opportunities for discussions. This included reading a predetermined number of pages from *Meehaneeto* as a group, with two camp facilitators acting the parts out. Following the reading, participants would have a discussion focused on the themes apparent in *Meehaneeto* in the daily reading, led by camp facilitators. After the discussion on *Meehaneeto*, a camp facilitator delivered content tailored to the theme. For example, if the pages had overarching themes of data collection, the morning input would be focused on defining data and determining when and how data is collected. Each day consisted of a 15-minute break, during which participants were asked to consider a question related to the ethics or social dimensions of artificial intelligence. For example, students would be asked to think about whether an AI that decided who was accepted into a university could have any negative implications.

The latter portion of the day was dedicated to larger-scale projects such as Teachable Machine, Scratch, and Dancing with AI. The content came from a combination of resources and included lab-developed content, MIT AI + Ethics curriculum for middle school, and the MIT Dancing with AI curriculum. Because the participants had varying levels of block-coding knowledge and AI literacy, we also took into consideration scaffolding daily activities and building competencies over the course of the week. Due to the nature of most AI activities, the challenges were individual. Despite this, students were divided into breakout rooms for two primary reasons: 1) Breakout rooms were enacted to ensure students felt more comfortable/less intimidated to share their work, and 2) Facilitators could more readily communicate and keep track of students with technical difficulties or the need for individualized support. Students ended the day by answering a prompt related to the days' content and recorded it using the multimodal digital application, Flipgrid.

4.2.2.1 Camp Schedule

Table 4.1

Camp Schedule General Overview – Specific details changed each day

Time	Activity
12:00	Welcome & Minds-On
12:10	Reading *Meehaneeto*

12:20	*Meehaneeto* Discussion
12:30	Introduction to the day's content (Input, videos, games)
1:30	Brain break (15 minutes) and discussion
1:40	Breakout rooms for individual projects
2:45	Flipgrid reflections
3:00	Camp end

4.2.2.2 *Meehaneeto* Thematic Breakdown by Day

Meehaneeto was used as a vehicle through which to facilitate conversations surrounding AI and ethics. As previously noted, AI camp may be a very rare instance in which participants were given opportunities to critically think about AI and the social implications that exist. *Meehaneeto* was used as an anchor in the camp: Each day began with reading approximately ten pages of *Meehaneeto*, with facilitators reading aloud. A graphic novel was chosen to bolster students' understanding and allow them to draw parallels from the sci-fi story and their own everyday lives. Prior to camp, researchers sent an email to registrants with a PDF copy of *Meehaneeto* attached. Researchers recommended that participants pre-read *Meehaneeto*, but this was optional as participants would read it over the course of the camp. Before camp started, *Meehaneeto* was analyzed for the commentary on technology integration and AI in society and a chart was devised based on themes and questions that could be integrated into camp discussion (see table 4). Camp proceedings were then tailored to match the themes and commentary of each day's reading. Below is a summary of the events in *Meehaneeto*, the emergent themes of the text that subsequently underpinned each day, and the question prompts discussed after the reading. These prompts served mostly as a springboard or icebreaker to help campers' thinking regarding parallels between the events and character motivations in *Meehaneeto* and their own lives. They were not required to answer the prompts and were encouraged to share their own thoughts outside of the scope of the prompt.

Table 4.2

Meehaneeto theme breakdown by day

	Meehaneeto Events	Commentary	Questions after Reading
Day 1	The main characters are at the wall, the daughter is curious about *Meehaneeto*, and learns about the difficulty accessing the distant land	Foreshadowing of potential dangers of accessing this new world (world of technology & AI)	What do YOU think "*Meehaneeto*" means? Why do you think a wall is separating *Meehaneeto* from the characters?
Day 2	They are having a picnic by the river, connecting with nature, daughter practicing high jumping with a bamboo rod to eventually leap over the wall	Mirroring the curiosity and desire to explore and develop with technology in the real world (steam rolling ahead without properly considering ramifications of development and	Why might the mother be distrustful of Petateeto at first? How do you think re-integration will affect the characters' lives and society?

		ethics)	
Day 3	Back at the wall, this time with the bamboo poll, the daughter makes it over to where the *Meehaneeto* were. She discovers the desolate landscape there now but also a piece of technology (resembling a scooter) that she retrieves and brings back. Mameeto forewarns that no good will come of the new technology.	Foreshadowing of the isolation and dangers that will come with this new technology.	Can you draw any parallels between the story and our own society? What might Panopteeto be reminiscent of in our real lives?
Day 4	Integration of new technologies throughout the Eleuseeto world as a result of this first technology.	Commentary on how quickly and how ubiquitously the technologies spread and how they impacted this society (concerns introduced like privacy, social connection, lack of exercise and connection to the natural world)	What did you find most challenging about Smart Assistant programming and what did you do to overcome these challenges? What would be some things at home that you would like to have a smart assistant for? Would this be useful, why or why not?
Day 5	Exploration of the latest technology – Panopteeto (AI).	Commentary on the type of control AI technology wields in our society and the question of "now what"? Where do we go from here?	The mother in *Meehaneeto* says that technology will always be unethical. Do you agree? Explain.

Table 4.3

Daily overview of Day 4's camp schedule

12:00 PM	Welcome and Evening Question
12:10 PM	*Meehaneeto*
12:20 PM	Smart Assistant Building
1:00 PM	Brain Break
1:20 PM	AlterEgo Viewing Choose Your Challenge
2:45 PM	Flipgrid Reflections
3:00pm	Evening Question

4.3 Participants

The camp was advertised to students entering grades 6, 7, or 8. Participants ranged from ages 12 to 14, entering grades 6 to 9. Guardians of the students completed the registration form along with an informed consent that specified the nature of the study. The consent noted that there would be recordings (both audio and video) of camp proceedings for the purposes of data collection and analyses, though parents could opt out of this if desired. At the end of the registration period, 18 campers were enrolled. Three participants opted out of both audio and video recordings, four opted out of video recordings, and eleven students consented fully to both video and audio. However, prior to camp start, two guardians emailed the researchers with news that their children who had previously registered and signed consent forms were now unable to attend due to unforeseen circumstances. An additional four participants did not attend camp at all, despite being registered. On the first day of camp, twelve campers attended. Two subsequent participants (both girls) stopped attending camp at various points. Two others occasionally attended the camp, either coming on some days or coming in and out of the Google Meet over the course of the day. Overall, there was on average eight active participants during the week. These eight participants consisted of five boys and three girls with varying levels of block-coding experience. Participants possessed a wide range of self-reported block coding experience. Most participants responded with “none” or “limited”, which was surprising to the researchers and facilitators.

Table 4.4

Participant Demographics (all names are pseudonyms)

Name	Sex	Age	Self-Report Block Coding Experience

Sophie	F	10	I have limited experience with block coding
Kamea	F	12	I have a good amount of experience with block coding
Armin	M	13	I have a good amount of experience with block coding
David	M	10	I have limited experience with block coding
Ami	F	13	I have no experience with block coding
Hassan	M	14	I have no experience with block coding
Zohan	M	12	I have no experience with block coding
Ryan	M	13	I have no experience with block coding
Daniel	M	10	I have limited experience with block coding

Hannah	F	N/A	I have limited experience with block coding
Kiara	F	12	I have some experience with block coding
Peter	M	N/A	I have no experience with block coding

4.4 Facilitators

In addition to the participants and two researchers (who did not actively participate or lead in the camp), two facilitators were employed to deliver content, supervise groups, and attend or help participants with data collection. The facilitators were referred to as "camp counsellors" within the camp and to the participants. To recruit two facilitators, the STEAM-3D Maker Lab sent out emails to current research assistants and previous STEAM-3D Maker Lab camp counsellors. The first facilitator was a former B.Ed graduate of Ontario Tech U's Bachelor of Education program who will be referred to as Facilitator 1. The second facilitator was employed as a graduate research assistant at the STEAM-3D Maker Lab and was recruited via a lab email asking for interest in joining the camp's team as a facilitator (Facilitator 2). Both facilitators had previous experience in assisting the STEAM-3D Maker Lab's virtual camps. In addition to the author of this paper, who acted as researcher, a second researcher also participated for the purposes of gathering observational field notes. The second researcher did not play a role in analyses or writing of the current thesis.

4.5 Virtual Context

Due to provincial health regulations set in place with regards to COVID-19, the camp was held entirely online in a digital format. Prior to camp, an email was sent to all registered participants containing links to the Google Meet and information on how to log in. A PDF copy of *Meehaneeto* by Janette Hughes and George Gadanidis was also attached for students to read ahead of camp (this was optional but encouraged). The camp was held on Google Meet due to its accessibility (no downloads or sign-ups required), its breakout room features, and overall ease of use. Daily camp proceedings and information were presented in the form of Google Slides using the "share screen" function. Supplementary visual information and other websites were also shared. In certain instances, participants engaged in activities that took place outside of Google Meet, such as Jamboard, Teachable Machine, Scratch, and supplementary and exploratory activities such . These supplementary links were shared with participants using the chat feature of Google Meet. One activity did require campers to use an internet browser's search feature and to save images to their computer.

4.6 Data Collection Tools

The instruments used to collect data for the camp varied widely. The following provides a more detailed examination of each tool used to collect qualitative data. The table below may serve as a quick visual reference to explain what data source contributed to each research question.

Table 4.5

Data sources and corresponding research questions

Data Source	Research Question 1	Research Question 2
Pre-Survey	X	X
Chatbox	X	X
Observation	X	X
Audio and Video Recording	X	X
Artefact Collection	X	X
Flipgrid Responses	X	X

Post-Camp Interviews	X	X

4.6.1 Registration Form

The registration form was developed in collaboration with the STEAM-3D Maker Lab's manager. The registration form was advertised on various social media websites such as Facebook, Twitter, and Instagram. Participants provided demographic information and answered a Likert-type question on their experience with block-coding in order to better contextualize their experiences within the camp and to gain better insight into the pre-existing knowledge and preferences of campers upon beginning the week. The registration form can be located in the appendix.

4.6.2 Pre-Study Questionnaire

The qualitative pre-study questionnaire was developed to gather information related to participants' baseline attitudes towards technology use, perceptions of artificial intelligence, and preferred digital learning apps and tools. Demographic information along with a self-reported Likert-scale responses in regard to block-coding experience were collected previously during registration form. All questions were open-ended, and participants could type short or long-form responses in the boxes with no word limit. The pre-survey questionnaire also served to inform the shifts in thinking that occurred during the camp by comparing the themes to the semi-structured interviews that took place on the last day of camp.

4.6.3 Camper Observation

Smiley (2015) described field observation as "an ethnographic practice of collecting data and information about a given social setting and situation" and noted that this method is "often used in preliminary research to have an understanding of the community one is researching" (p. 1812) and gathers this information through methods such as field observations, sound recordings, and field notes. Camper observations were recorded through digital and physical field notes. Essential to gaining personal narrative context to develop accurate case studies, field notes allow researchers to observe participants in a naturalistic setting (Creswell, 2013). Most of the preliminary field notes were "jottings" (Emerson et al., 1995) and descriptions of interactions or behaviours that could possibly inform subsequent data analysis. I sought to record any potentially meaningful responses, interactions, or artefacts that relate to the overarching themes of the camp. Due to the two facilitators present, I was able to spend the full amount of time recording and collecting observations, resulting in a large amount of data. After the camp ended for the day, facilitators and researcher took part in a meeting, lasting approximately 15-20 minutes, and compared our recollections from the day to assess whether any information was missing or inaccurate from another perspective. Once the meeting concluded, a refined set of notes was added into a Google Drive folder, where they were accessible to the whole team.

4.6.4 Chat Box

So as not to place undue pressure on participants, they had the option of speaking on mic or using the chat box to interact. The issue of the best ways to collect and make meaning from digital chat data has been a long-standing area of consideration as evidenced by Orthmann's (2000) exploration of online chats as meaningful data. Because the camp was contained within a virtual environment, the chat box served as a parallel to what may be considered "natural conversation" between facilitator and peer and peer-to-peer. Chat box interactions were monitored during the camp's proceedings. Interactions and responses were noted in the researcher's field notes, in addition to being collected (through copy and pasting) for further analysis. The camp often relied on discussion-based learning, the facilitators would either prompt over microphone or chat box to ask follow up questions and relied heavily on the chat boxes to supply data.

4.6.5 Flipgrid

Flipgrid (founded in 2014, acquired by Microsoft in 2018) is a multimodal video platform that allows students to record video responses to prompts supplied by educators or other students. Due to its asynchronous nature, Flipgrid has been recognized as a tool that can provide ways for students to demonstrate their learning and thinking during the COVID-19 pandemic and remote learning (Bauler, 2021). Flipgrid was chosen as a tool for several reasons. The first reason Flipgrid was selected as a tool was to engage participants multimodally. While developing the camp, it was predicted that campers may be less inclined to contribute to chat real-time where they may feel shy or uncomfortable with peers. Flipgrid has been investigated as a way to promote social learning (Stoszkowski, 2018). Flipgrid had also been used as a tool in past camps and research projects developed and delivered by the STEAM-3D Maker Lab. Research colleagues had mentioned its usefulness for data collection and keeping. Users are able to view and comment on others' videos and teachers or facilitators are able to seamlessly track views, comments, and overall participation. These reasons, coupled with its strong privacy ethos made it an appealing choice to utilize for this study.

4.7 Ethics

An informed consent was signed by the parent/guardian and participant before completing registration in the camp. Researchers communicated with participants and parents/guardians to ensure that each party was aware that they were able to withdraw from the camp or the research study at any point during the week. The camp was free to attend. In lieu of a fee, registrants were made aware that their data and details of participation would be subject to data analysis for research purposes. The camp was essentially marketed as a "free research camp" and was explicit in its purpose upon registration. In email communications with participant guardians (e.g., "Thank you for registering" emails, preparation emails), it was reiterated that the camp was plural-purposed: To help campers gain critical thinking skills surrounding AI, to build AI technical competency skills, and to collect data from the participants to use in a research projects. The REB introduction letter and consent form can be found in the appendices.

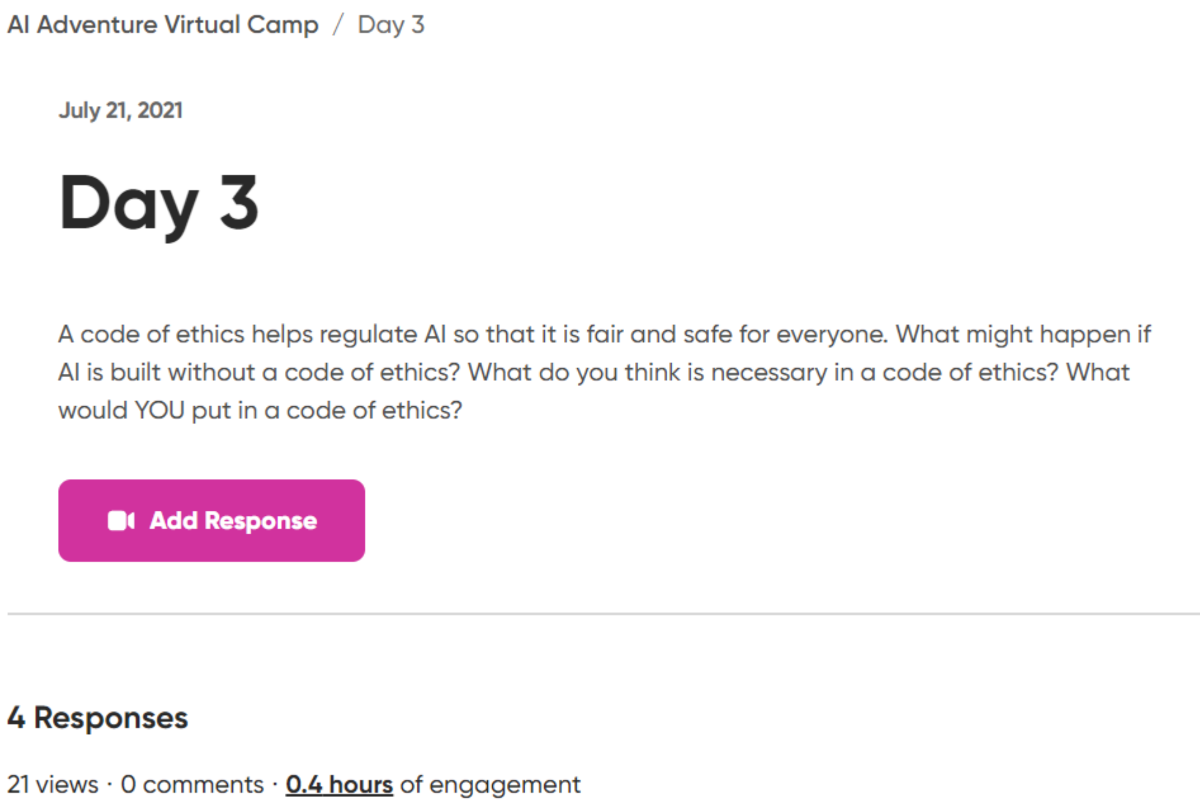
4.8 Data Analysis

Qualitative data analysis is an intuitive practice that aims to draw conclusions from the data sources using a variety of methods. I conducted thematic content analysis (Berg, 2007; Creswell, 2013;) to analyze campers' work. Their communications in the chatbox, ideas, work, and interviews were analyzed via thematic content analysis to draw out emergent themes (Braun & Clarke, 2006; Creswell, 2013). Braun and Clarke (2006) describe these themes as relating, on some level, to the research question. I created a digital spreadsheet that mapped different sources of data and filled each with analytic notes. I conducted a first impression coding cycle - Pulling out a number of specific themes. In a process that aligns with Saldana's (2016) process of cyclical coding, the first cycle of coding typically highlights a number of participant ideas before grouping them into larger categories based on overarching themes in a second cycle of coding (see appendix for coding methods). During the second cycle of coding, I grouped the codes into broader and more comprehensive groups, which I denoted as categories. The categories group the codes of the same nature into a larger, more comprehensive group. From these categories, they were further grouped into overarching or main themes. These overarching themes represent the experiences and shifts in thinking experienced by campers over the course of the camp and are underpinned by the categories and codes that emerged from the process of cyclical coding.

The analyzed data came from a wide range of sources, with the richest data resting in the pre-surveys, post-interviews, Flipgrid responses to end-of-day questions, and chatbox discussion. Flipgrids were an interesting medium to analyze, because they are insulated moments without influence from facilitator's questions. Flipgrid allows a snapshot into participant thinking without additional input that may bolster more discussion or elaboration. However, this means that Flipgrids are a one-way street – students did not monitor their Flipgrids outside of camp, thereby eliminating means for researcher clarification or follow up on sentiments expressed during their recordings.

Figure 4.1

Screenshot of Day 3's Flipgrid page and discussion prompts



There were four responses added to Day 3's Flipgrid, despite the 8 participants present that day. This limits the amount of data that can be drawn from certain sources and also limits the data to the participants who recorded the Flipgrid. I created separate coding sheets for each data source for ease of use. Within these sheets, I attempted to find themes relevant to each research question that also aligned closely with the frameworks that informed the study. For each participant, I analyzed their contributions using the previously mentioned data sources and grouped emergent themes. From this preliminary analysis in which I began coding words, phrases, and ideas into larger themes that would be explored in an in-depth manner through case studies. The process of coding was inductive, a ground-up approach to coding that begins with data, rather than codes. This was the preferred method of coding because it allows for a more open-ended or exploratory approach to locating emergent themes. As per Strauss and Corbin's (1998), inductive coding presumes the researcher begins "with an area of study and allows the theory to emerge from the data" (p. 12). Deductive reasoning, on the other hand, is more suited for research that deals with hypothesis-testing and program evaluation (Thomas, 2019).

The findings are presented in such a way that an overview of the emergent theme is presented first, followed by case studies of participants that showcase particularly demonstrated shifts in thinking. Case studies were selected based on campers with the most complete data sources and whose camp experiences illustrated the coded themes most effectively. Due to the online nature of camp, many participants did not complete tasks, share their screens, or participate in meaningful ways. The case studies were constructed and informed by Stake's (1995) perspectives of case study methodology. The pillars of Stakian (1995) methodology are founded by constructivism and non-determinism, meaning that knowledge is constructed by the learner, rather than absorbed or "discovered" (Stake, 1995, p. 99) due to the nature of knowledge being something that is internal and subjective. Saldana's (2016) cyclical coding processes work to remove explicit bias in interpretation and complement the case study format. Due to the multiple sources of data, participants who generated fuller and more prolific data were chosen for the case studies. There were instances of co-occurrences, when statements fit two or more codes, as the statement may be long, complex, or refer to more than one concept or idea. An example of a statement that was coded for two categories, is "Teachable Machine worked most of the time, so that was fun. It was fun to train the different things to recognize all the different stuff. Had never done anything like that before." This statement was coded for both novelty ("had never done anything like that before") and Teachable Machine.

At least one research question presented in the study (namely, "What were the shifts in thinking that occurred during the course of the camp?") requires comparative methods in order to properly address it. In each study, particular attention is paid to the growth of the participant by reviewing their initial (pre-study and early) attitudes and conceptions of AI and comparing it to data that illustrates a development or lack thereof. In summary, the methods employed for data analysis are qualitative: Saldana's (2016) cyclical and inductive coding to draw themes from the data sources together with Stakian case study methodology will expectantly produce the most insightful and reliable findings.

Chapter 5

Findings

5.1 Overview

The study's primary objectives were to shed light on the campers' shifts in thinking surrounding AI, particularly surrounding the ethical implications of AI that occurred over the course of the virtual camp and the main contributors to how the camp design accelerated or inhibited these shifts. Below the findings from the analysis are presented. Each research question is presented and followed by a comprehensive analysis of participant data as it relates to each emergent theme. Within the emergent theme, case studies are then presented. Stakian case studies accompany each section as a means to further explore the findings and provide situational descriptions of participant experiences over the course of the camp. These case studies are used to provide specific and contextualized information and draw more complete conclusions about their shifts in thinking that occurred and the elements of the camp that bolstered or inhibited said shifts. The case studies presented are individualist, interpretive, and Stakian in nature.

5.2 Building Personal Definitions of AI

The first research question developed to guide this thesis is, "What are the shifts in thinking (pertaining to artificial intelligence and critical thinking) that occurred in participants as a result of the camp?"

3. What design elements of the camp contributed to the shifts in thinking of participants?

The objective of this question was to explore the pre-conceived notions participants held of AI and how they evolved during the five days. Presented in this section are the findings that resulted from an inductive, cyclical content analysis, supported by case studies that exemplify the emergent theme. "Shifts in thinking" were analyzed using interpretative and comparative qualitative approaches. The pre-survey and post-surveys were salient wells of relevant data for comparison as they revealed a "pre-definition" and "post-definition". The pre-survey is used as a baseline measure of student thinking. Shifts in thinking were deemed to occur when there was a marked change or growth in the initial response or when students presented novel attitudes and ideas than previously presented. Similarly, Flipgrids, student work, observations, and discussions also provided insight into how students were developing over the course of the week. To fully assess the potential shifts in thinking, it is imperative to analyze the results of the pre-survey to gather a robust understanding of how participants conceptualized AI prior to camp. Participant definitions can also be thought of as "descriptions", as they are not so much as defining AI but describing what AI means to them personally and the ways that AI applications are used or could be used.

Overall, the camp seemed to have a positive effect on participants beginning to develop a more balanced understanding of AI. At the outset of this camp, many participants had rudimentary understandings of AI, and most had similar views on the relationship between AI and humans (E.g., AI is made to help humans). This was to be expected, as the ethical implications and other ways AI interacts and influences our lives is seldom a topic of conversations in schools and most personal interactions with AI seemed to be "helpful assistants, according to their pre-survey answers to the question (Siri, YouTube, and Netflix were common examples when asked how they use AI). The definitions of AI students provided at the end of camp were mostly much more sophisticated, realistic, and balanced than those provided pre-camp, suggesting that AI camp had a positive effect on developing understanding of AI. Prior to AI Adventure Camp, definitions of AI were not complex. Gauging or evaluating the development of understanding of AI is a difficult task due to the wide variety of AI as well as the complexity of its definition. However, comparing their pre-survey definitions to their post-interview definitions highlighted the development, or lack of development, in their understanding. Instances that are believed to have contributed to growth or demonstrated growth between providing definitions are outlined in this section.

In the pre-survey, participants were asked about their personal definitions of AI to achieve a baseline of how they perceived AI and the ways they believe AI intersects with their daily actions. Below is a chart that displays answers to the question, "How would YOU define artificial intelligence?". The participants responded with mixed ideas – three campers mentioned robots in their definitions and or included references to the simulation/mimicry of human intelligence. Ami's response was an interesting departure from her peers – She defines it as something "mysterious and far away" from her, but believes it has something to do with general "technology". This response indicates that perhaps Ami does not see AI as something directly influencing her daily life in significant ways but reserves it as something for the future. However, Ami further indicated she uses technology at home via tools like the refrigerator and the dishwasher. It is unknown if she has "smart appliances" and could be referring to IoT integrations but does demonstrate creative and/or divergent thinking as this was the only example of smart appliances produced by participants.

Table 5.1

Coding of pre-survey responses that reflect different concepts when defining AI

Camper	How would YOU define artificial intelligence (this does not need to be a Google definition, but rather what you think artificial intelligence is)?	Code
Kiara	To me AI is, robots and computers and other tec.	Robotics
Daniel	Robotics	Robotics
Kamea	Intelligent technology, programming, robots	Robotics
Armin	I would define artificial intelligence as a simulation/duplicate of human intelligence in machines that are meant to mimic humans.	Human intelligence mimicry
Zohan	I think it is about Technology	Technology
Sophie	A computer or program that thinks by itself to do something.	Unassisted intelligence
Hassan	Artificial intelligence is machines that are designed to think and act like humans.	Human intelligence mimicry
Ami	I define artificial intelligence as something that is mysterious and far away from me. It's something to do with technology and people always say that one day, it could replace humans.	Technology

Armin had a particularly sophisticated response, noting that he believes artificial intelligence to be a simulation created to directly mimic human intelligence. Most of the ways the campers use technology at school is for this like research, virtual manipulatives, “to do work”, and presentations.

Another pre-survey question campers were asked was to list three things that come to mind when they think of AI. This question was added to gauge the technologies that participants most closely associated with AI and if those technologies are representative of everyday AI use. Moreover, this question can contribute to assessing whether participants had realistic or unrealistic ideas of how they are engaging with AI and the ways AI influences their lives. This is an important question that can provide additional context when examining the process of defining AI that was seen during camp: What are the common items/services/applications that campers think of as AI and did those change? Their answers shed light on what they think of as AI and how these beliefs apply to their understanding and personal definitions of AI and the influence of AI on daily human life.

Table 5.2

Summary of pre-survey responses providing examples of AI

Camper	**List at least three things that come to mind when you think of A.I.**
Kiara	Robots, coding, and computers
Daniel	Technology, robots, phones
Kamea	Cool, fun, smart
Armin	Social Media, JWA (Game with AI), Smart devices and digital voice assistants like Google Mini or Siri

Zohan	Coding, robots, phone
Sophie	Robots, computer and machines
Hassan	Android, robots, and automation
Ami	Robots, Siri and self-driving cars

The examples of things campers provided when asked what comes to mind when thinking about AI ranged broadly but campers often cited “robots”, “computers”, and “phones”. Armin indicated one of the most sophisticated responses, “social media, JWA (game with AI), Smart devices, and Digital Voice Assistants like Google Mini or Siri”. Ami also provided a sophisticated response with “Robots, Siri, and self-driving cars”. When asked if the campers thought their examples were realistic, many responded that they did feel their examples were realistic. Armin explained “I think they are realistic representations because they are seen and used in everyday life in the present”. Ami indicated “I’m not really sure and I don’t really know.” Zohan indicated “Yes because robots and phones robots etc. are not real so they are artificial intelligence”. The responses indicate that they associate AI with technology in general and have little nuance to them.

Table 5.3

Summary of pre-survey responses about AI and impacts of daily life

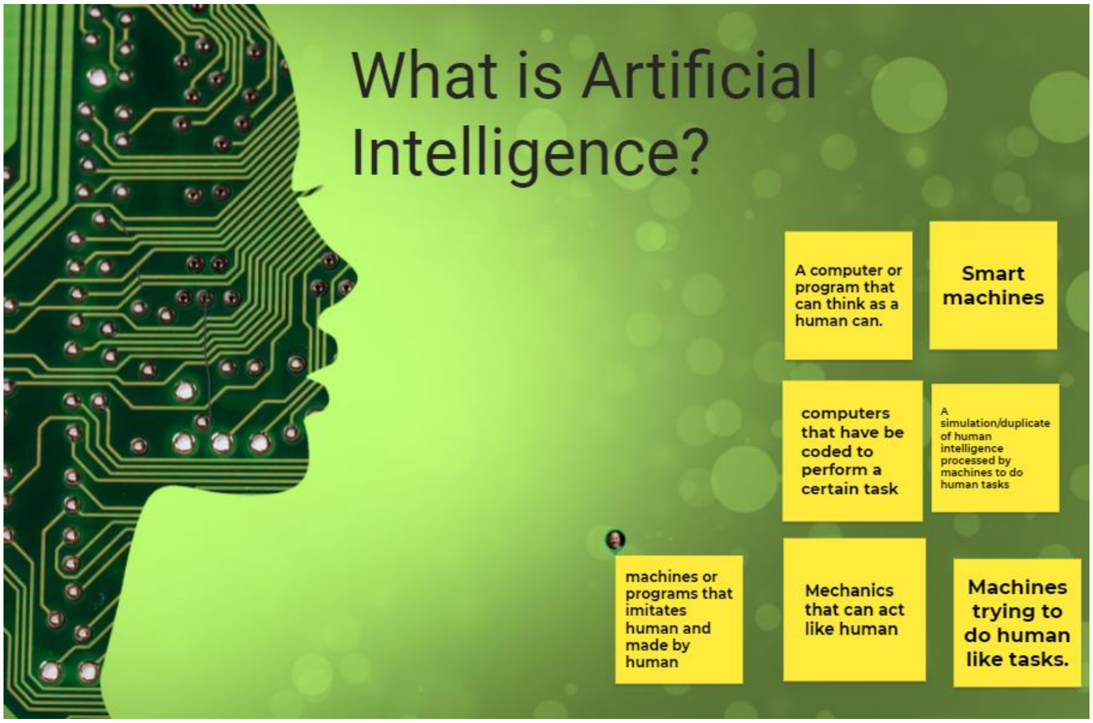
Camper	How might A.I. impact your daily life?
Kiara	My dad keeps going on about it

Daniel	messaging and talking to friends
Kamea	Instead of going outside or reading book I would play on my phone
Armin	Simplify, enhance and assist
Zohan	We need A.I as currently, smart devices, digital voice assistants and social media is growing in use.
Sophie	A.I. can make our daily lives easier
Hassan	AI doing things that I usually do.
Ami	It makes my life more easier and more convenient.

On day one, campers were asked to complete a Jamboard answering the prompt, "What is Artificial Intelligence?"; this was a minds-on question at the outset of camp. Prior to answering this question, we had read an excerpt of *Meehaneeto* in which the main characters (a mother and daughter) are discussing what *Meehaneeto* is. The daughter grows curious about *Meehaneeto* and comes to learn of the distant land that can no longer be accessed due to a large wall built around it. The primary themes of this excerpt were foreshadowing of potential dangers of accessing the world of *Meehaneeto* (The world of technology and AI). After this, a short discussion was had about how the campers' perceptions of *Meehaneeto* and why there is a wall separating *Meehaneeto* from the characters. We also touched on what AI is in a technical sense, the types of AI (strong, narrow, digital, and physical). After this, almost all of the Jamboard answers defined AI within the confines of their relationship with humans. At this early stage of camp, their answers also referenced the mechanisms underpinning AI, citing the programming, coding, and mechanics in their answers.

Figure 5.1

Day 1 Jamboard responses to "What is Artificial Intelligence?"



It is important to note that this theme, *Building Personal Definitions of AI,* is separate from the theme below, *Engaging in Critical Thinking of Ethical AI*, because defining AI does not necessarily encompass ethics or social dimensions of AI, although it could. The first table presented in this section displays the camper's name and their answer to the pre-survey question, "How would YOU define artificial intelligence?". This was selected to present in this section as it directly relates to the emergent theme *Redefining Personal Definitions of Artificial Intelligence.* It is important to consider their initial response to gauge how and in what ways their post-camp definitions shifted. At the end of camp, the campers completed a short interview that revisited many of the questions that were asked in the pre-survey. The post-camp definitions are included in the table below. Their responses were compared to their previous answers and have been analyzed to discern whether they include more complexity (e.g., pre-definition of "robots" to "robots that use AI to mimic or imitate natural intelligence possessed by humans/robots that are used by humans to complete specific tasks), expanded criteria (e.g., "AI is a robot" to "AI is a robot that performs a specified function"), and whether or not the definitions showed more balanced thinking (e.g., "AI is something that helps humans" to "AI is something that helps humans if used responsibly"). This included using the coding process and applying codes when the new definitions contained more complexity (marked by more sophistication in the way they presented their idea of AI), expanding criteria (this could be marked by providing more examples of what and how AI functions), and more balanced (showcasing critical thinking via detailing ways in which AI has both positive and negative outcomes in society or on individual users).

Table 5.4

Summary of post-interview definitions of AI

Camper	How would you now define A.I.?	More Complex	Expanded Criteria	More Balanced
Kiara	N/A	N/A	N/A	N/A
Daniel	AI is something that you will be able to control and mostly using technology to learn or recognize human's voice, face or something	Yes	Yes	Yes

	humans usually do. Yes [there are concerns with using AI].			
Kamea	I would define A.I as technology that can learn and help us with everyday activities...I think A.I could have some technical problems: Malfunctions, A.I not working, maybe it might be biased.	Yes	Yes	Yes
Armin	A simulation/duplicate of human intelligence in machines programmed to think and act like humans and help humans with problems they face.	Yes	Yes	No
Zohan	Man-made intelligence and technology.	Yes	No	No
Sophie	[Did not answer]	N/A	N/A	N/A
Hassan	AI can be simple or complex, you can look outside your window and see examples of AI helping humans in some way	Yes	Yes	No

Ami	A.I teaches a computer or a program to do something on its own to help humans or do a task.	Yes	Yes	No

At the end of camp, Hassan wrote that his biggest takeaway from camp was, “All technology isn’t just a moving robot – it can be in your phone or something and it doesn’t have to be walking and talking.” This seemed to mirror many of the participants’ overall takeaways from camp as well. Most of the participants’ answers to this question highlighted that their original perception of AI was much more robot-centric, and that camp shifted their thinking into a more mundane or everyday view of AI. This is significant, because it is critical for youth to view AI as more than humanoid robots that are represented in media, so that they can understand that they engage and use AI daily and the responsibilities that come with this.

A lens through which participants tended to view or conceive of AI is through their own personal interests and values. Many participants stated, when asked after the Smart Assistant programming activity, that they would choose to have a Smart Assistant to do their homework for them, or referenced their favourite media representations of Smart Assistants, such as Jarvis from the Iron Man movie franchise, which echoes the media representations of AI that youth seem to be familiar with and may view as realistic. However, AI Adventure camp seemed to have a positive effect on students’ growth in thinking surrounding AI. Hassan wrote this of camp: “Used to think AI were just robots and stuff and realized they can be in computers and a ton of other stuff too. You can see it in phones, movies, ovens, etc.” Participants also showed a developing engagement with privacy and security concerns in their own lives. During a discussion about *Meehaneeto* on Day 5, the last day of camp, Armin wrote that "we give a lot of information to social media", with Daniel following up, "and Google", and Hassan jumping off of that with, "Google Maps". When asked for clarification about the kinds of information we give to these internet spaces, Daniel wrote, "Research information when you search on google", Armin wrote, "Like pictures of yourself", and Hassan wrote, "Your location when you use Google Maps". When asked about the concerns with data and privacy only a few days prior, the chat had been very quiet, almost nervous to answer, perhaps for fear of sharing ideas in an unknown environment. These ideas seemed to be self-generated, as in, these are not concerns we explicitly talked about during camp. Campers may only need exposure to these conversations and ideas before making their own meaning and connection from it. Even so, at the end of camp, campers still often situated themselves in their perceptions of AI. For instance, when asked about what kind of AI they would like to build, many campers responded with AIs that would help them with tasks, such as homework, or taking out the garbage. As Armin stated in a Flipgrid reflection, he would like an AI to "help me take out the trash because I live in a condo and the hallways are creepy when it gets dark". Another camper reported they would like an AI like Jarvis in Iron Man, who is not a realistic representation of the function of current AIs. Although camp seemed to lay a strong groundwork for developing more realistic and complex descriptions of AI and helped campers shift their thinking in modest ways from personal-to-societal costs and benefits of AI, there should still be more sustained education on human-AI relationships and ethical AI literacy.

5.2.1 Case Studies

Case studies are chosen based on the amount of data generated by each participant. Camp was hosted online, and it was difficult to track engagement and participation among the group. Many participants, although they provided excellent insight into their thinking in certain instances, were inconsistent in their participation spanning across all facets of camp (discussions, sharing screens and artefacts, Flipgrids, interviews, etc.). Even campers who were engaged in the chatbox would fail to respond to Flipgrid prompts, or some days would not be present in the chatbox at all. = Two participants, Kamea and Armin, had much more complete data than the other campers. Kamea and Armin consistently provided responses, answered prompting questions, and provided Flipgrid responses which illustrated a more thorough picture of their growth throughout camp. Therefore, Kamea and Armin have been highlighted for each of the themes drawn from the data. Their experiences, thinking, and growth are distinct enough to present each of them as a separate case. Other participants simply did not provide enough insight into their camp experience to generate a suitable level of meaningful data for a *case study*, but their data is still used to generate findings and themes.

5.2.1.1 Kamea

Kamea was 12-years-old at the outset of camp. Her favourite things to learn about, according to her pre-survey, are “science, coding, and art” and she is familiar with virtual manipulatives and computer work through her schooling. She prefers to learn about her interests through experimentation and group work. This was apparent in her enthusiasm and participation during the camp. She was one of the most engaged campers throughout the week, often typing in chat and providing reviews of activities without the facilitators having to ask for participant thoughts (e.g., "This is really cool!"). Even so, it was difficult to get Kamea to share her screen, use the microphone, or talk to other campers, even though she noted social learning as a favourite way to learn.

Kamea showed some of the biggest shifts in thinking overall in building a more complex and balanced definition of AI. Comparing her pre-camp definition to her post-camp definition is quite striking. When asked to provide what AI meant to her, her pre-camp definition was simple: "Intelligent technology, programming, robots." On day one, it was written in the observation field notes that Kamea was one of the participants who was consistently interacting with the content of camp; this trend remained steady over the five days. Kamea was generally engaged with discussion and offered insights and opinions into videos, activities, and conversations. She often reflected on how AI is useful to not only herself but other humans. For example, after watching AlterEgo, Kamea was the first one to offer the suggestion that the AlterEgo technology could "help people with disabilities". Despite not being a prominent focus of the camp, Kamea's thinking showed a degree of flexibility and balance by weighing the potential benefits and negatives of AlterEgo.

At the end of camp, when asked again how she would define and describe AI, she wrote: "I would define A.I as technology that can learn and help us with everyday activities…I think A.I could have some technical problems: Malfunctions, A.I not working, maybe it might be biased", which, compared to her pre-camp definition of, "Intelligent technology, programming, robots", was an impressive improvement in terms of reflecting nuance and critical thinking. Her final definition shows her to believe that AI is something that is developed exclusively to help humans and also references how AI can “malfunction”, resulting in bias. This is interesting, because AI bias is not so much as a “malfunction” but a result of underrepresentation in data sets. It is unknown whether Kamea believes that AI bias stems from mistaken errors in AI or if she does not have the vocabulary to describe the systemic cycles that underpin much of the biases in AI. Nevertheless, her personal definition of AI was certainly more sophisticated at the end of camp. Her description of AI “malfunctioning”, though, reflects her ability to for critical thinking and her knowledge of how AI manifests itself in everyday life. Kamea, from her post-camp definition, seemed to absorb much of the information around bias we discussed while also being a stand-out camper in terms of offering positive and responsible uses of AI as well. Her new description of AI drew on some of the topics we discussed in order to engage campers in critical thinking, such as bias. In her new description, she also offered her opinion that AI can help people in everyday activities. It was much more balanced; she discussed both affordances and potential consequences of AI in society. Compared to her original definition, Kamea showed marked growth in understanding AI and weaved this understanding into her personal descriptions.

5.2.1.2 Armin

Armin, along with Kamea and Zohan, were consistently engaging with the chatbox, offering their insights without being asked, and generated discussion between peers. His pre-camp description of AI was, “I would define artificial intelligence as a simulation/duplicate of human intelligence in machines that are meant to mimic humans.” His primary conception was that AI is developed to mimic human intelligence and he often asserted his belief that AI is a complex program. At many points throughout the camp, Armin espoused his perceptions that AI and robots are synonymous, or, at least, very closely related and interchangeable terms. When asked what he was excited to learn about during camp, he answered, "robots". Despite this, Armin's primary interest was the environment and the ways AI and the environment intersect. Armin was much more forthright about his personal perceptions of AI; on day 2, reported that he was surprised to learn that algorithms actually strive to be efficient and simple. In his Flipgrid, he reported that this was his biggest takeaway of the day. "Camp made me realize that we humans are surrounded by A.I. It doesn't have to be complex". Which is a departure from some of his earlier sentiments. Throughout camp, Armin consistently engaged in thought exercises, answered questions in chat, and was enthusiastic about the AI-based games and activities we played. At the end of camp, he post-definition of AI was not largely different from his first definition, but there was a key shift. His post-definition, of AI, "A simulation/duplicate of human intelligence in machines programmed to think and act like humans and help humans with problems they face", was very similar to his first definition of AI, however, he added the component of "helping humans". His work throughout camp was often reflective of big-picture thinking, citing environmental and physical implications of AI, and activities such as building a recyclables classifying algorithm paired with the speculative fiction elements of *Meehaneeto* in which humans and technology eventually have a balanced and ethical relationship may have helped Armin's thinking grow in this way.

5.3 Engaging in Critical Thinking about AI

A second theme that emerged in the data is the process of engaging in critical thinking about AI. AI Adventure Camp was designed to provide campers with multiple avenues to engage in critical thinking: through discussion, design fiction, videos, and activities. The “Critical Thinking & Critical Literacy” section of the front matter within the Ontario curriculum has this to say about the actions needed by students to invoke critical thinking:

> “Students need to ask themselves effective questions in order to interpret information; detect bias in their sources; determine why a source might express a particular bias; examine the opinions, perspec-tives, and values of various groups and individuals; look for implied meaning; and use the information gathered to form a personal opinion or stance, or a personal plan of action with regard to making a difference.”

This includes making connections between AI and bias, evaluating the positives and negative aspects of AI, considering the ethical implications of AI (both positive and negative), using “big picture thinking”, problem-solving, and generally developing a more sophisticated philosophy of AI. When considering the ethical implications of AI, participants were most concerned with environmental and social impacts of AI and the ways AI impacts their own personal behaviours. As camp progressed, instances in which campers analyzed their own relationship with AI in critical contexts emerged. For example, Hassan reflected on his own personal relationship to technology, stating:

> We spend a ton of time on electronics and stuff and I'm realizing that we spend way more time on electronics than going outside or something. AI "kind of" controls our behaviour because sometimes I would think of going outside and then my friend calls me and he wants to play a video game so I never end up going outside.

This reflection shows some degree of critical thinking and considers how he, in the present, is impacted by AI. This sentiment aligns with critical theory of technology, a pillar of the theoretical framework enacted in this research. Hassan, in this sentiment, muses that technology and/or videogames impact his relationship to the outdoors, which is a theme that was touched on throughout camp in *Meehaneeto* and environmental-based coding activities, for instance, the Teachable Machine-Scratch integration that sorted paper, plastic, and glass using participant webcams.

At the beginning of camp, most participants, when speaking of robots, seemed to insert them into the category of "friendly helper". For example, when asked about examples of things that come to mind when thinking about AI, campers shared things like "robots", "computers", and "phones". Armin provided one of the most sophisticated responses: "[I use AI by engaging with] social media, JWA (game that uses AI), smart devices and digital voice assistants like Google Mini or Siri". Ami, in response to the same question, also provided quite a complex response with "Robots, Siri, and self-driving cars", providing examples of both physical AI (such as robots) and digital AI (such as Siri). Moreover, in the pre-survey, when campers were asked about how they interact with AI, Hassan, who seemed to be quite a reflective camper and often made connections to his personal behaviours wrote, "Instead of going outside or reading book, I play on my phone".

Examining Daniel's answer to the question presented in the table below, it is interesting that, at the end of camp, he describes AI simply as something you (likely referring to humans in general) controls. On one hand, this sentiment perhaps reflects some degree of agency over AI and an awareness that humans are the "beginning" of any AI application: that humans control AI through writing programs for AI and ultimately infusing particular beliefs and biases into said programs. On the other hand, it may demonstrate that there has been little development in the understanding that AI algorithms (such as Netflix or YouTube) often change and adapt to our interests without our explicit awareness. Despite requests for clarification and exposition, Daniel did not offer it. However, from his first answer, "weird", there does seem to be some sort of shift in thinking surrounding the human-machine relationship.

Table 5.5

Comparison of participant answers evaluating their descriptions of human-AI relationships

Camper	**How would you describe the relationship between humans and A.I.?**	**How would you now describe the relationship between humans and A.I.?**
Kiara	N/A	N/A
Daniel	Weird	AI is something that you can control.
Kamea	People make machines and machines help people	If you had artificial intelligence daily life and chores would be much easier…Google maps, it helps

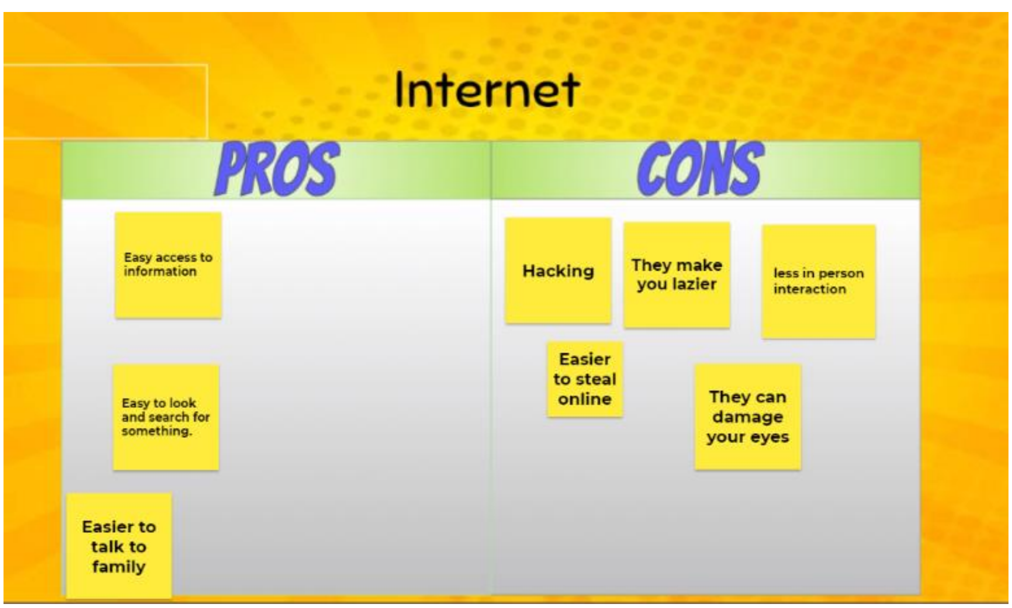
		everybody in the world see where they want to travel. But security might be a problem. when there is an accident there will be news online instantly and when there is a case of COVID-19, the health agency website or the news will report the case instantly. Humans can control AI with coding and face recognition and AI can replace in a factory, car wash, and more.
Armin	AI can help humans in their everyday life and AI can acknowledge more people that humans might not even know.	It would not be different but I feel more strongly about it now. AI has negative and positive effects and there is bias in AI.
Zohan	Some A.I. Robots can replace humans in the future in cafes, supermarkets, and more.	N/A
Sophie	Useful	A.I teaches a computer or a program to do something on its own to help humans or do a task.
Hassan	I'm not sure	N/A
Ami	AI is made by human but it's	N/A

	smarter than human.	

On the first day of camp, campers completed a short minds-on activity in which campers contributed to an anonymous Jamboard with their pros and cons of the internet. Prior to this activity, campers had a short input session on the history of the internet and what life was like before the internet. As all campers were younger than 14, it was necessary to contextualize that both the internet and AI are relatively new inventions and have rapidly changed the world in a short period of time. The relative recency leads many areas, particularly education and ethics, ill-defined and not yet fully realized in terms of how they should be implemented into society. Below the Jamboard of campers' answers is presented: There are a wide variety of responses, from social networking to physiological repercussions of technology use (e.g., eye damage).

Figure 5.2

Jamboard featuring anonymous post-its citing pros and cons of the internet

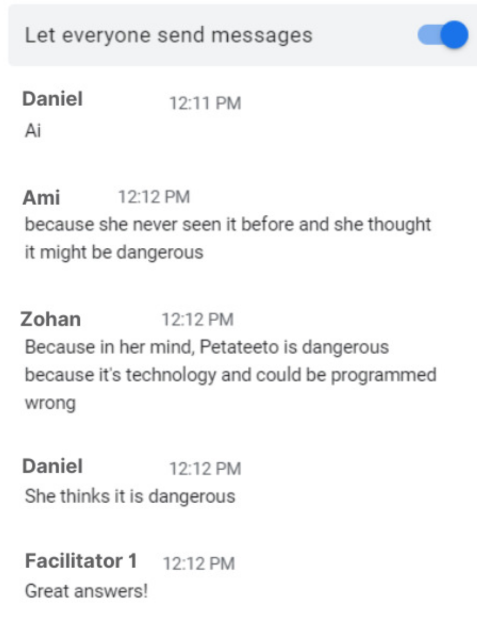


At this point in the camp, we had only read a small amount of *Meehaneeto* and had very limited discussions on what *Meehaneeto* means to both the readers and the characters. This is significant because this list was generated strictly from pre-study thinking, as we had not yet discussed much of the potential ramifications for AI. Though this was a very early activity, there were more post-it-notes on the "cons" side compared to the "pros" side, perhaps suggesting that participants need only small amounts of discussion and guidance before generating less-than-ideal potential issues stemming from technology.

On Day Two, it was difficult to engage campers in discussion around *Meehaneeto*. Initial field notes revealed: "No takers for Meehaneeto questions - very difficult to get them to respond." It seemed perhaps students were more unsure of the camp and what may be expected of them on this day. After the facilitators reminded campers about what Panopteeto meant, this opened up the discussion a little more. Campers to the question presented, "Why might the girl be worried about Panopteeto?" by using the chatbox.

Figure 5.3

Chatbox responses to Day 2 Meehaneeto discussion



In the image above, Zohan speculates that technology may be programmed in a way that could be dangerous - In fact, most respondents in the chat mention "danger" as a possible reason why the girl may be wary of *Meehaneeto*. Due to participants' reluctance to share thoughts on mic or in chat, the Jamboards were open to post on either anonymously or with a name.

There were some instances within camp discussions that reflected an awareness of bias within AI. For example, during breaks, there was a question left on the slides for campers to consider while they were away for the 15 minutes. The question posed was, "Is an AI that decides who gets into college and university fair? Why or why not?" After break, Zohan wrote in response,

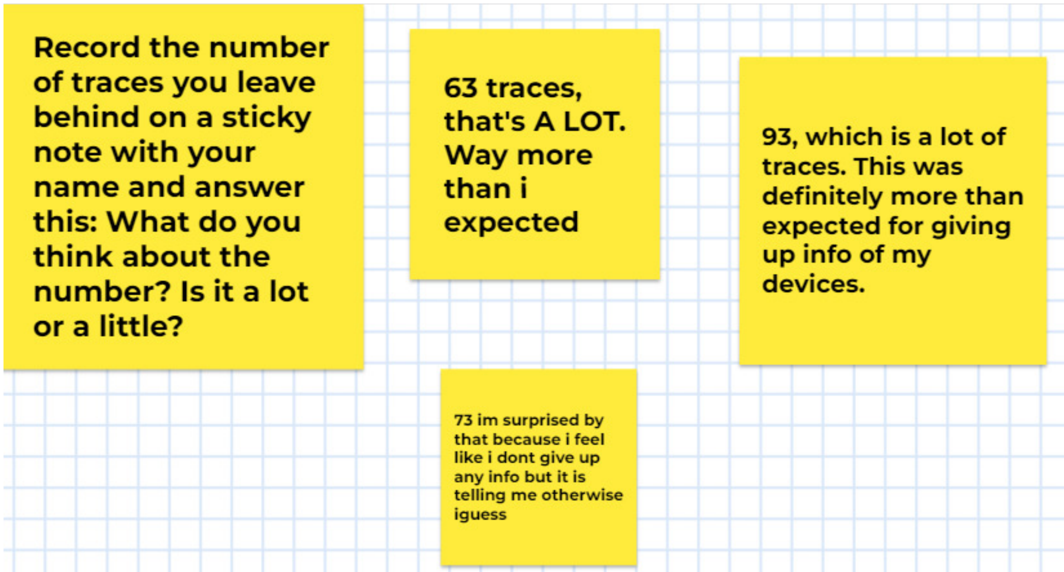
> The A.I. has to be programmed by someone and if that someone knows about how university and college decide who gets in and who doesn't, then yes, it is fair because they would've probably put their opinion in the programing.

Zohan's answer demonstrates a developing understanding of AI biases and the ethical implications within real-world contexts. For example, he has absorbed, in some capacity, the concept of the fundamental of bias in AI (that AI biases can come from personal biases or worldviews) and he believes that an "expert" in the field of knowing "how university and college decide who gets in and who doesn't" is a better outcome for all applicants than someone who is not an expert or may be explicitly biased. He is suggesting that his purported programmer, through their expertise, will mitigate bias and unfair outcomes as they will have the knowledge to program the algorithm "correctly". Of course, even hypothetical programming experts can be prone to unwittingly using a biased dataset through cultural perspectives and contexts or a myriad of other external factors. For example, a programmer from North America creating a dataset of fruit may not include fruit outside of their common cultural experiences. Despite this, Zohan's answer does suggest a burgeoning understanding of AI bias and critical thought when considering fairness and ethics of real-world AI problems.

Digital footprints were not largely understood by campers. There were many instances in camp where participants seemed surprised to learn about their digital footprint despite not willingly or knowingly given up information.

Figure 5.4

Responses to the activity Trace My Shadow, names from responses removed

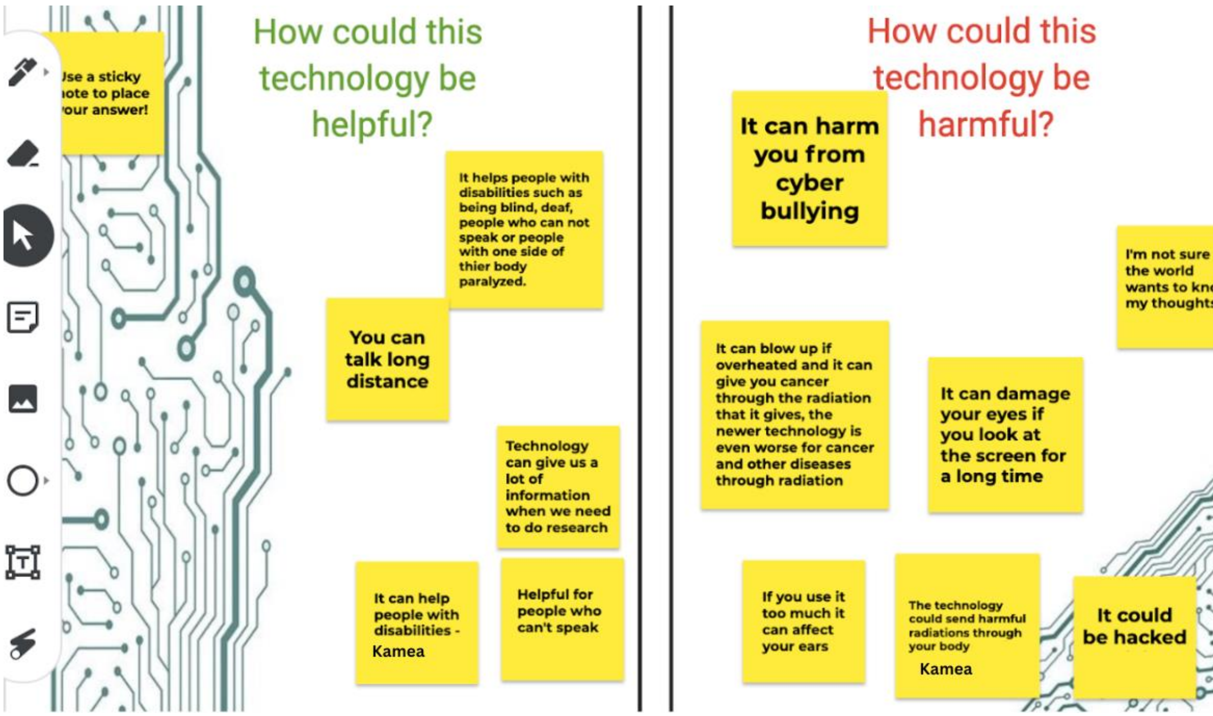


The campers who responded seemed surprised that they had such a high number of "traces" (or contributions to a digital footprint). However, after a facilitator discussed digital footprints, campers co-created a Jamboard in which they added applications and logos that they believed were contributing to their digital footprints. Gaming consoles, computers, phones, and social media were all included in the image, which may show some degree of understanding, compared to the limited knowledge they possessed and the surprise they displayed when looking at their "trace numbers".

The image below is a Jamboard after watching *AlterEgo: Interfacing with devices through silent speech,* a YouTube video by MIT Media Lab about a real device that allows the wearer, "to converse in natural language with machines, artificial intelligence assistants, services, and other people without any voice—without opening their mouth, and without externally observable movements—simply by articulating words internally." (MIT Media Lab, n.d.). This video was selected because it has obvious positive implications, but also has potentially negative ramifications in certain social contexts and echoed some of the themes we highlighted in camp such as human-AI relationships and the way AI shapes or adapts to our world.

Figure 5.5

Thoughts regarding the technology featured in the video, "AlterEgo"



The post-it notes on this Jamboard contained an interesting selection of ideas from participants. Surprisingly, mirroring the other Jamboard, there were more ideas on the "negative" side than the "positive". There was much consideration for the physical changes and impacts that integrated AI can have on humans. One post-it note reads, "It can blow up if overheated and it can give you cancer through the radiation it gives. The newer technology is even worse for cancer and other diseases through radiation," while another reads, "if you use it too much it can affect your ears." Physical implications were concerns that came up during discussions and activities, despite not being an outright theme of the camp. Physical implications as negatives were mostly raised solely by participants in discussions. It could be that participants were building off of each other's ideas, seeing one physical implication using it as a "jumping off point". Another post-it note references cyberbullying as a potential harmful impact, but it is unclear how the *AlterEgo* technology could facilitate cyberbullying – This camper may be referring to ways the internet could potentially facilitate cyberbullying rather than focusing on *AlterEgo*. AI and technology in general provide multiple avenues for cyberbullying but is also being used to eliminate cyberbullying and hate in online spaces (Al-Marghilani, 2022). Perhaps the post-it note is referring to technology in general as an avenue for cyberbullying. There is one comment that shows concern for hacking, but the most common theme is the physical implications. Interestingly, there was a similar theme on the positives side, with many post-it notes citing the positive implications for those with physical disabilities. During camp, participants had opportunities for critical thinking through various avenues. However, it seems that *Meehaneeto,* Flipgrid reflections, and daily questions generated the most outward discussion. Sometimes, participants were completely silent. It may be that they did not yet have enough experience with AI – its limits, affordances, realistic perspectives of such technology – to draw speculation from. It was noted that critical discussion was helped, that is, more responses from participants were generated, when there were facilitator prompts or facilitators modelled imaginative thinking. Participants did show some development in critically thinking about ethical implications of AI. When asked on day 3: "A code of ethics helps regulate AI so that it is fair and safe for everyone. What might happen if AI is built without a code of ethics? What do you think is necessary in a code of ethics? What would YOU put in a code of ethics?" Ami gave the following response in her Flipgrid video:

> Okay, so for my opinion, I think that I probably would put 'fair, kind, and...respectful' in a code of ethics because those three points are my perspectives for me. I think that this is the most important point that an AI must have. Yeah, that's my opinion.

For this question, Ami seemed to show a developing understanding of what "ethics in AI" refers to. Her response was limited in her own thinking; she seemed to repeat "fair" which was mentioned in the question and did not provide her thoughts on what happens if AI is not developed *without* a code of ethics. However, she added "kind and respectful" from her own perspective. Ami did not go into detail about why she believes that these are the most important things an AI should have.

5.3.1 Armin

Armin, age 12, uses technology in his day-to-day life, mostly through videogames and social media. He was a very engaged camper and was eager and enthusiastic about the discussions and activities during camp. Armin was the first camper to use the mic feature on Day 1. Armin's critical thinking became more prominent through the week and was especially displayed at times when he spoke about his interests, namely biodiversity, the impact of AI on biodiversity, and the environment. When Armin joined camp, he seemed to hold mostly positive ideas of AI and offered his opinions on how interesting and "cool" AI is, writing, "AI can help humans in their everyday life and AI can acknowledge more people that humans might not even know." However, Armin came to camp with a great capacity for nuanced and balanced thinking. He was often able to give both negative and positive ethical implications of AI. For example, he wrote: "AI can harm the environment but also is good for having quicker answers to questions, less employment in a job." His critical thinking, particularly in regard to environmental impacts of AI was excellent, and he often infused this into his thinking process. Harking back to his answer on Day 2 when discussing *Panopteeto,* he wrote in the chatbox that the girl sees *Panopteeto* as dangerous, and he quickly understood this was an allegory for AI in our own lives, which is one connection that was not commented on by other participants at this point in camp. He was especially interested in complex versus simple AI, usually bringing up the fact that AI can indeed be simple and efficient rather than complex in nature as a prominent revelation brought on by camp.

In his post-interview, Armin wrote: "Camp made me realize that we humans are surrounded by A.I., it doesn't have to be complex". Moreover, Armin often frames his thinking about AI in terms of the environment, which he mentioned at the beginning of camp as a very personal interest of his. "AI impacts the ecosystem…because this is probably in the future, things like komodo dragons or leopards that are hard for humans to get rid of and kill and leave out of our environment could be eventually killed by AI and that would cause a imbalance food web of the predators." His use of "probably in the future" aligns with the design fiction narrative *Meehaneeto* encompasses: Armin is using *Meehaneeto*'s design fiction to conjure possible realities of our future and offers some, although limited, critique of this possible future.

During a discussion following a reading of *Meehaneeto*, Armin wrote, "AI impacts our daily life more and more every day as we build new technology and become dependent on AI to assist us, AI is almost always needed to do daily things". Armin framed AI in such a way that suggests he believes humans are dependent and growing more dependent on AI applications.

Again, this is reminiscent of a design fiction, a very early stage of one, as he speculates that we continue and will continue to grow more enmeshed with AI. His awareness of this human-AI relationship was rare in the camp – Many campers did reference relationships between humans and AI, and it was common for campers to comment on the ways in which AI helps humans, but Armin's use of the word "dependent" was unique. This implies a negative connotation, indicating that Armin understands that there may be drawbacks of a complete dependence on technology. During camp, Armin often reflected on his own use of technology. On Day 5, we completed an activity called, "Trace My Shadow", in which you fill out a questionnaire-like page that asks questions about devices you use, Armin wrote, "63 traces, that's A LOT. Way more than I expected", in his post-it note on the Jamboard. Armin, overall, seems to have developed in terms of his depth of critical thinking, often linking his concerns of AI to the environment. Camp hopefully validated some of his pre-existing concerns about biodiversity, while also providing some guidance towards hope if AI and technology are used ethically and responsibly.

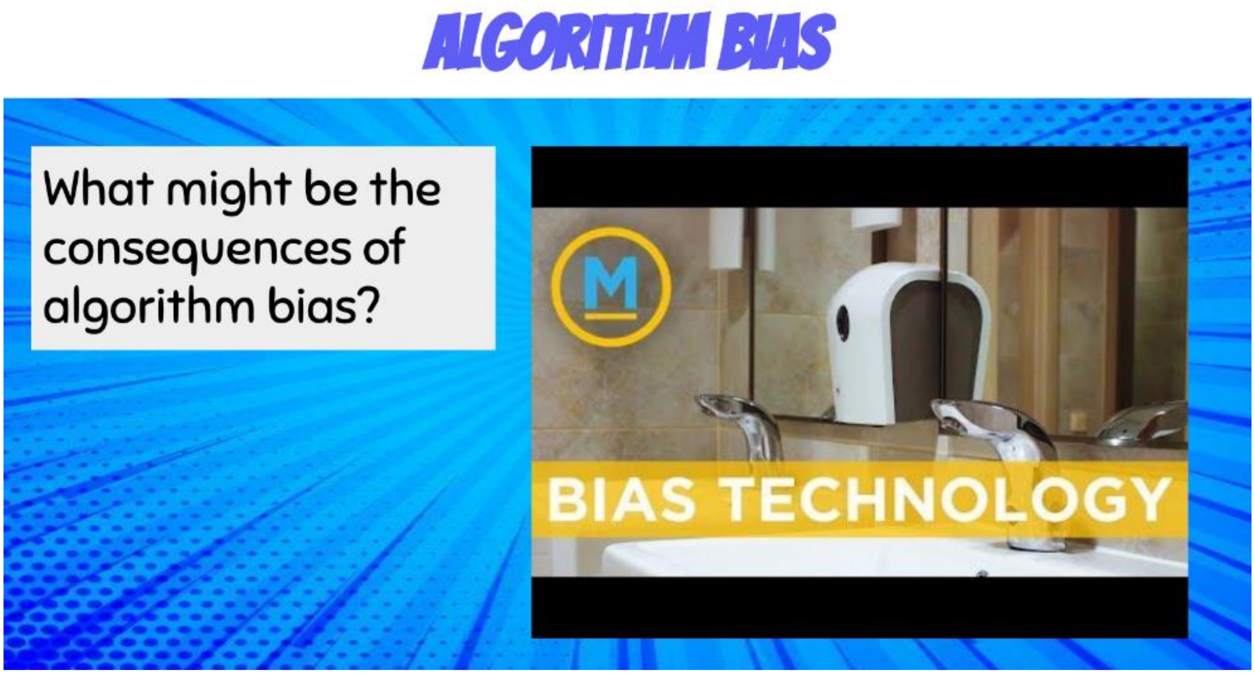
5.3.2 Kamea

Kamea, 12-years-old, was one of the students with the most pronounced shifts in thinking over the course of the camp. In the pre-survey, she reported that her favourite technology applications are BrainingCamp and KnowledgeHook. B Allison's preferred way to learn about technology are through "experimenting, working in groups, and using new tools". In fact, on day one, the researcher observation notes had the following written in regard to her pre-survey responses, "Kamea appears to have the most difficulty defining AI and giving specific or accurate examples" The note went on to provide an interpretation of this, reading, "Her responses were short and did not particularly contain depth or examples of understanding – This may be due to a misunderstanding or perhaps she has limited data on which to base her definitions or examples." Another instance of Kamea's difficulty in this area is when she was asked, "What are three things that you think of when you hear 'AI'?", and she responded, "cool, smart, fun". The prompt was actually asking for specific examples of AI, but the wording was (intentionally) vague in order to not influence the direction of participants' thinking, however this could have been misinterpreted as asking for adjectives to describe AI. Kamea was the only participant who interpreted the question in such a way. It is difficult to pinpoint the cause of the misunderstanding – It may have been the vagueness or perhaps Kamea just required more information before she can offer more developed examples, as we had not yet started camp and most participants began with limited understanding of AI. However, it may prove to just be the result of a misinterpretation, as Kamea provided a more sophisticated answer (compared to other participants) to the pre-survey question reported above (What are three things that come to mind when you think of AI?) in **Table 5.2**, citing "intelligent technology, programming, and robots".

Kamea's initial ideas of AI seemed to be entirely positive at the outset of camp. When asked in the pre-survey "How might AI impact your daily life?", she wrote, "simplify, enhance, and assist", and did not include any negatives in this. When prompted in a further question in the pre-survey, "what are some positives *and* negatives of AI?" She responded, "Positive: Solutions to big problems, makes life easier, innovations," and "Negative: Less socializing and gratitude for others, job impacts, hacking, malfunctions". This might indicate that although she recognizes AI can have negative impacts, they are not something that will or could affect her daily life - She only considers the negatives if prompted to think about them explicitly. During camp, Kamea was engaged and willing to participate in camp activities. She was also one of the only campers who consistently completed Flipgrid reflections at the end of the day. Her Flipgrid reflections were creative – she opted to use creative font selection and varied background patterns and colours with a voice over instead of using the webcam to speak.

Figure 5.6

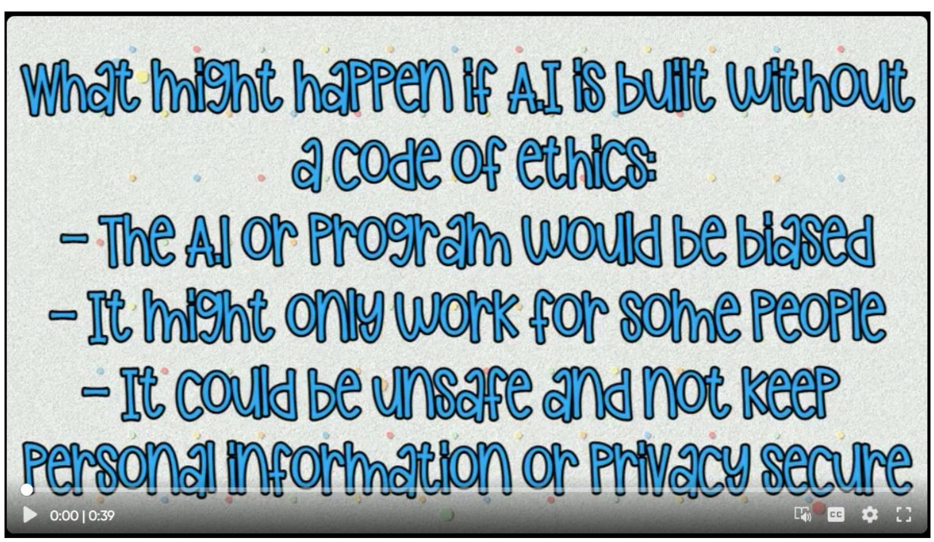
Screenshot of a slide titled "Algorithm Bias" presented alongside a video and a discussion question



On Day 3, Kamea made the following response to the question: "What might happen if AI is built without a code of ethics? What would YOU put in a code of ethics?" "What might happen if AI is built without a code of ethics: The AI or program would be biased; It might only work for some people; It could be unsafe and not keep personal information or privacy secure.” She then moves on to her next point in the video: “What I think is necessary in a code of ethics: security and privacy; free of bias and fairness to everyone”. She then concludes with what she would put in a code of ethics: “What I would put in a code of ethics: The users should use the AI responsibility; The AI will not use personal information without consent; The AI should be programmed to be fair to everybody”. Her response does indicate a degree of critical thinking and indicates she absorbed some information from the activities and discussions she had participated in. In her response, Kamea indicates that she believes that ethics (particularly, codes of ethics) can help eliminate bias in AI. Kamea’s consideration for social biases was considerably higher than her peers’ in her responses. Her critical thinking was stand-out; she consistently engaged in chat discussions and activities.

Figure 5.7

Kamea’s Flipgrid response to the question, “What might happen if AI is built without a code of ethics?”



In Kamea's post-interview, she did note her concerns about security and AI, a topic we explored in day 4 of camp. Kamea wrote, "Security might be a problem. When there is an accident there will be news online instantly and when there is a case of COVID 19, the health agency website or the news will report the case instantly. Humans can control AI with coding and face recognization and AI can replace in a factory, car wash, and more." This was much more complex than many of her peers' responses. Despite being in the middle of a global pandemic, most campers did not bring up the circumstances of the health crisis. Kamea, however, did, and despite her sentiment being a tad unclear, her big-picture thinking seemed to be a theme during her time in the camp. During camp, Kamea displayed many instances of considering both personal and societal/global impacts of AI. If Kamea offered an idea for how AI might help her personally, she would typically follow it up with how it would help others in different ways. For instance, when asked about the impacts of AI on society she wrote, "Daily life and chores would be much easier," before writing, "Google maps, it helps everybody in the world see where they want to travel." Kamea further noted, "During camp, I learned that A.I can be biased and there are ways that you can program it to not be biased" but she did not elaborate further on the methods of how AI bias can be mitigated or eliminated from algorithms, but she noted she did not know about AI bias prior to camp and then included mention of it in her final personal description of AI. Despite this, this reflection shows some degree of critical engagement with the content. It does appear she gained some deeper understanding of the ethical issues and concerns surrounding AI discrimination and bias. Kamea's Flipgrids were consistently reflective and engaging – Each day, she presented her thoughts on the screen through text and then read them out clearly and confidently. She chose different fonts and backgrounds to accompany her video responses each day. Kamea's thoughts are communicated efficiently and neatly. In her post-interview, she wrote TV was one method she engages with AI (she did not include TV in her pre-survey). When asked for clarification on the role of AI in watching TV, she shared: "For example, Netflix when you watch something, there are suggestions based on what you watched". This was an interesting example, as she did not include TV in any of her pre-survey responses but did mention TV in her post-interview. Kamea likely constructed knowledge based on the camp content about AI bias and algorithms and recommendations on Netflix and was one of the only campers who mentioned algorithms and Netflix to such a detailed level in the post-interviews. Kamea displayed many instances in which she engaged in reflective and critical thought and will hopefully continue to pursue an ethical and responsible relationship with technology that demonstrates the same degree of consideration and interest that she illustrated during her time in camp.

5.4 Meehaneeto

A digital pdf copy of *Meehaneeto* was distributed to the campers upon registration. In the welcome email, campers were welcomed to read *Meehaneeto* prior to camp, but there was also a message that reported we would be reading it as a group each day. The choice to read *Meehaneeto* prior to camp was up to each individual camper. On day one, *Meehaneeto* was read at the beginning of each day independently. However, it was difficult to gauge how invested campers were or if they were even reading the novel. The chatboxes were sparse when asking discussion questions. During a post-camp day researcher-facilitator meeting (these were completed directly after camp each day to discuss observations, gain feedback, make adjustments to the next day's plans), it was decided that to ensure campers were actually reading or engaging with *Meehaneeto,* the researcher and a facilitator would read out the pages, playing specific characters. After this change was made, campers quickly seemed to become more invested in the story and the campers became more willing to share thoughts and ideas based on the discussion prompts. Using a graphic novel as an anchor or centre point of the camp seemed to be a positive feature to most campers. Graphic novels are becoming increasingly embraced as important facets of literature in the classroom (Downey, 2009; Wallner & Barajas, 2020; Block, 2013). *Meehaneeto* was divided into themes as the story progressed, and these themes corresponded to the overall topics of the day. The format of graphic novel, which presents narrative information in both pictures and text (and eventually voice), may be useful for readers' ability to synthesize data and information due to the added context the dual modality provides (Morrison, 2017). On day one, we began reading excerpts from *Meehaneeto* as a group. When asked what the campers think *Meehaneeto* means, there were three answers in chat: Machines (Daniel), a more modern world (Kamea), and AI (Sophie). Some students, such as Ami and Hassan, enjoyed *Meehaneeto* for the parallels between their lives and the narrative, where others engaged with *Meehaneeto* in a way much more akin to a speculative fiction. For instance, Kamea's answer to the previous question may suggest that she views *Meehaneeto* as a possible, but not-yet-here future. When the campers were asked what themes they believe come up in *Meehaneeto*, she wrote, "Innovation and ideas", again using *Meehaneeto* as a vessel of imagining possible futures.

To gauge whether or not using literary narrative and metaphor in a digestible graphic format was of any benefit to developing an understanding, participants were prompted to answer the question, "How did the graphic novel, Meehaneeto, help you better understand issues surrounding A.I.?" during the post-interview. Campers responded with generally positive assessments of incorporating *Meehaneeto*. Even when campers were asked about positive general features and tools used in camp, campers often included *Meehaneeto* in their list of favourite parts of camp. For example, when Daniel was asked about the tools that helped him the most during the learning activities, he responded with, "Some activities like scratch, machine learning, and Teachable Machine helped me to learn about what the AI can do and can learn or recognize your face or voice, and the *Mehaneeto* graphic novel help me to understand how AI can help in our daily life." *Meehaneeto* was the vessel for many important conversations that helped participants reflect and think critically about AI.

5.4.1 Armin

> "Meehaneeto if that's how you spell it, helped me better understand AI because it kind of teaches us the benefits and drawbacks of AI, and how we shouldn't be too sucked into it...it is electronic and I've learned that can send radiation to your brain which can cause cancer, also that AI can be harmful to biodiversity... and also the waste."

Armin has a marked interest in biodiversity. He often relates both learning and doing to the topic, even citing that he joined AI camp because he could not find a biodiversity camp. He often responded to *Meehaneeto* discussion questions and used *Meehaneeto* as a vehicle for discussion surrounding environmental implications of AI and technology integration in society. Armin shared that his enrollment in AI Camp was primarily because biodiversity summer camps were full, yet he was still able to find avenues to incorporate and relate biodiversity and environmental concerns into all facets of AI camp, including *Meehaneeto*. Armin held *Meehaneeto* in high esteem with regard to his shifts in thinking that occurred over the course of the week. "[That] AI can do and can learn or recognize your face or voice, and the *Mehaneeto* graphic novel helped me to understand how AI can help in our daily life." This was interesting, as *Meehaneeto* emphasizes two sides of AI: what happens when *Panopteeto* is overused and unregulated, and what a society that holds "old world" and "new world" values in balance might look like. Armin, in this case, does not mention any social implications, but rather physical and environmental implications. He does, however, address *Meehaneeto* in helping him understand environmental implications, but he does not elaborate on potential ways AI applications could be programmed to be equitable or safe for the environment. His revelation concerning the impacts of AI on biodiversity showcased his capacity for big-picture thinking and he recognizes that AI and technology do pose potential threats to the environment if used recklessly or if not intentionally created to protect the environment. Armin does share that he "learned" that AI "sends radiation to the brain which can cause cancer", which is not something we discussed or taught during camp. Armin may be referring to other campers' ideas, because there were a few anonymous ideas on Jamboard that reflected this line of thinking when asked various questions about the implications of AI. This drew attention to the fact that not only should we be presenting realistic representations of AI and machine learning in society, but we should also work to explicitly combat any misconceptions or misinformation students may have. This specific concern Armin has does not presently have a scientific consensus (Axelrod & Wilson, 2014). However, another thought he had regarding *Meehaneeto* was Therefore, not only should realistic examples and expectations for AI be presented (along with opportunities to uncover and investigate how AI is developed through constructionist activities), misinformation and misunderstandings should be addressed simultaneously.

5.5 Building Technical Competency through Coding

The focus on coding and incorporating technology-based lessons into the camp was intentional. As the primary goal of the camp in terms of outcomes was to bolster more critical and comprehensive understandings of artificial intelligence, AI Adventure Camp was designed to engage both domains of purported AI literacy. However, it was surprising that many of the campers, who presumably entered camp with a pre-existing interest in AI, had little to no experience with block-coding. Most campers, aside from Armin and Kamea who rated himself with a block-coding experience of 8 out of 10, described their skills as Even so, in the pre-survey questionnaire, using technology and the internet were common answers when prompted with questions about preferred ways of learning.

Despite this, in each post-camp interview, using tech-based tools, namely Scratch, was a consistent thematic thread when asked about factors that promoted engagement and understanding of camp material. Campers responded very positively to the coding challenges presented during the camp and these constructivist and/or block-coding activities seemed to promote technical competency. When Daniel, a camper, was asked what helped his thinking the most during camp he answered, “Some activities like scratch, machine learning and teachable machine helped me to learn about what the AI can do and can learn or recognize your face or voice.” Ami, a new Scratch user, had difficulties using Scratch in the beginning, but at the end of camp noted, “I explored and tried several times on how to train a machine and how to code on scratch and it went well. I didn't know much before camp and this week I learnt that you can program a sprite to make a sound when you open your mouth.” In fact, Scratch was referenced as a source of helpfulness and engagement among most all campers. Those who developed more nuanced personal definitions of AI also seemed to engage in more critical discussions and also displayed a better grasp of technical skill required for the activities. This perhaps suggests that technical competency (e.g., having a high degree of skill related to block-coding) somehow supports critical thinking related to AI. Perhaps understanding “back-end” mechanics of AI allows for more easily imagined realistic scenarios when it comes to ethical implications of AI.

Another factor that seemed to help participants’ understanding and build their technical competency was novelty and variety, a concept that was of paramount important to most campers. End-of-day Flipgrid reflections as well as post-interviews contained many mentions of exploration, novelty, and variety. Participants were often quick to note when an application was new to them. Hassan wrote, “Teachable Machine worked most of the time, so that was fun. It was fun to train the different things to recognize all the different stuff. I had never done anything like that before.” Campers began camp with little experience in block-coding, and by the end of camp, had programmed a “Smart Classroom Assistant” in Scratch that used text-based commands to create different effects on the Scratch stage. However, prior to this activity, campers were given a choice in AI-integrated Scratch activities to complete. For instance, they were able to integrate Teachable Machine to make a (virtual) phone turn on via webcam or images or could integrate Teachable Machine into a Scratch program that would display a Jellyfish whose emotional state would change depending on whether the user was smiling or not (as detected by the Teachable Machine model). In this activity, students' interests were able to be integrated into the activity. During these AI activities, campers worked both independently and communicated through text (chat) to any verbal inquiries from facilitators or researchers. Daniel and Kamea (who worked in a breakout room together as they were not given consent to have their video on, just their audio, text, and artefacts were to be collected), both completed the phone unlock program and showcased it through screen sharing. Kamea used her favourite singer's picture, Ezra Muqoli, to unlock her phone program.

5.5.1 Armin

> "It helped me better understand concepts related to AI because of being able to visually see it and have a good 3 hr period to understand it whereas in school and less descriptively taught and we have less time to understand and play around with things."

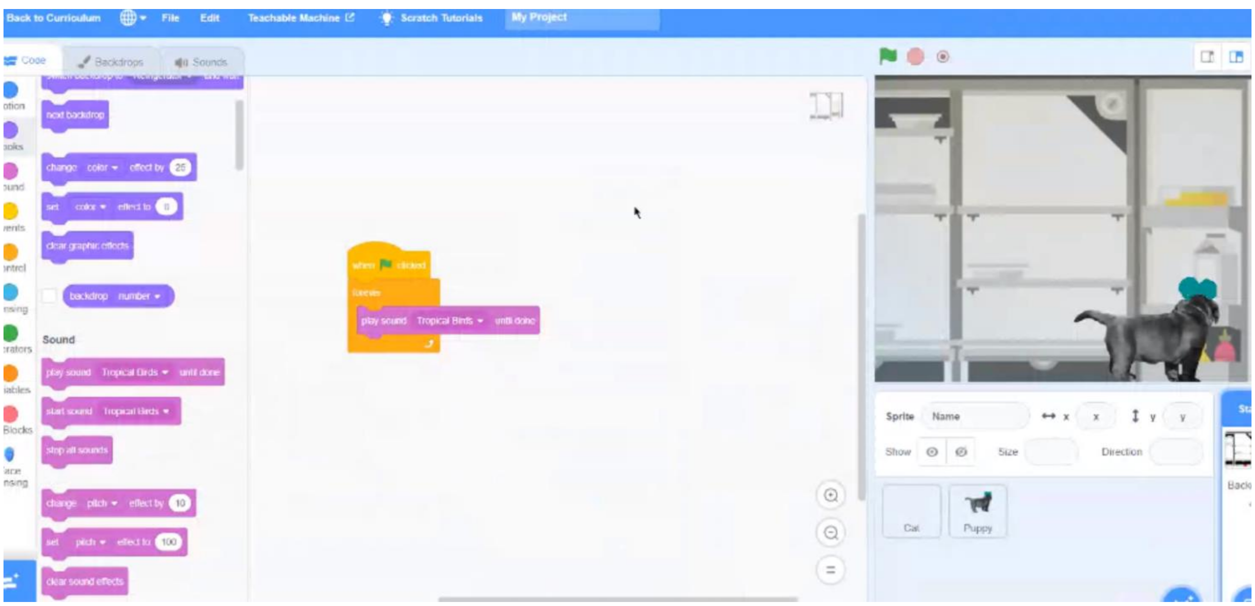
Armin, age 12 at the time of camp, reported his block-coding proficiency as "none". Despite this, Armin was very quick to adapt to Scratch challenges, remixing and building code with ease. When encountering problems, he often asked questions via chat, something he mentioned helped support his learning, “When I had problems I would just ask and that helped me.” Throughout the course of the camp Armin was consistently interested in all of the content presented but was particularly engaged and responsive during periods of coding and project-making. Despite this, screen sharing to visualize participant work and progress was still a challenge. Nevertheless, Armin consistently mentioned his enjoyment for the coding challenges in his Flipgrid reflections. He often made note of how the coding challenges helped him learn whatever concept we had focused on that day. At the time of his post-interview, he talked about Teachable Machine as a project he enjoyed, specifically the integration of Teachable Machine and block-coding. Armin reported the three-hour period as a supportive feature, rather than being too long or boring, which was a surprise considering a three-hour timeframe for a coding and AI camp was predicted to be a limitation for most campers. When asked how camp helped him understand concepts related to AI he wrote, “Camp helped me better understand concepts related to AI because of being able to visually see it and have a good 3 hour period to understand it, whereas in school it is less descriptively taught and we have less time to understand and play around with things”, before writing ”I found new websites I can use more often now and I learned more about Scratch than I was taught in school”. Armin’s evaluation, that camp was helpful because it was a dedicated three-hour topic allowed for a deeper dive into learning about Scratch and AI. In schools, Scratch is often taught with a cross-curricular approach, but in AI camp, Scratch was used as a vessel by which to understand the underpinnings of AI. This allowed campers to have more time to connect the concept of coding to AI, which is also perhaps why he felt he learned more about Scratch at camp than at school, because at camp, we were examining each element of the block-code as a fundamental piece of the bigger (an AI application). The concept of novelty was a strong theme for many participants, and especially for Armin, who enjoyed learning and using new technologies, websites, and tools. When asked about particular activities that helped him understand AI better, he wrote, perhaps unsurprisingly, “Scratch because I like doing things hands-on and trying something new.” He enjoyed using Scratch because he likes hands-on activities – Even though Scratch is a digital activity, he holds it in the same regard as a hands-on activity, which is supported by digital constructionism. The activities were, as Armin describes, “hands-on” in the sense that Scratch allows for the construction of digital making and production of digital artefacts. His final thought from his interview is that he gained experience with using Scratch and can now “implant my ideas into it”, which showcases the power of digital making tools and block-coding for students who are engaged and interested in it.

5.5.2 Kamea

Kamea came to camp with a self-reported block-coding sufficiency level of 8 (out of 10) in chat and responded with “I have a good level of block-coding knowledge” on the pre-survey. It was not clear if she had used Scratch or other programming platforms, as she referred to Scratch on day 1 as a tool she enjoyed working with, but later reported that she was happy that she was able to learn about a tool she had not tried before. During the first coding activity of camp, Kamea initially declined to share what she was working on but would offer feedback via mic or chatbox within breakout rooms to alert facilitators of her progress. When coding her first project, which was an introductory Scratch workshop and remix activity, she experimented quite a bit - Changing the sprite and stating how cool she found playing in Scratch to be. Over the course of the camp, she was engaged, enthusiastic, and participated in each activity. Kamea, when introduced to the coding challenge on day 1 (a simple scratch remix), took the time to remix the code and opted to add her own touches of music and sound effects, despite this not being part of the “remixing requirements”. Kamea eventually shared her screen within her breakout room, which consisted of only her, Facilitator 2, and another participant.

Figure 5.8

Kamea sharing her screen while working on a Scratch project featuring a dog



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Kamea continued to show enthusiasm for working with Scratch and block-coding overall and noted the novelty of a tool she had not used before. Although Kamea reported her block-coding skills as an 8 out of 10, it seemed Scratch was a new tool. She may have come to camp having practiced block-coding on a different platform.

Figure 5.9

Kamea in chat showing interest in her Scratch project

Kamea 8:22 AM

I'm adding some music

and sound effects

and

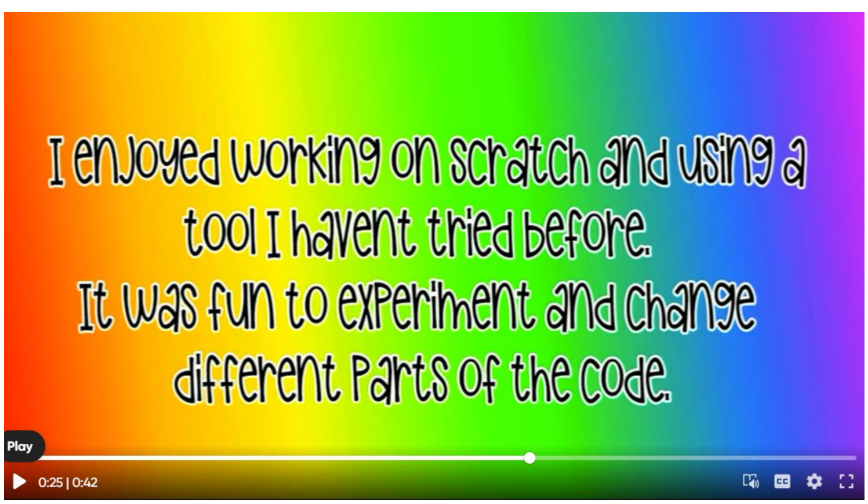
Kamea 8:28 AM
brb

Kamea 8:31 AM
This is cool!

She would often reflect on how much she enjoyed using new applications – She did often have questions, but still cited these activities as enjoyable. She had resilience to overcome her challenges, asking for help and experimenting until she had an "aha" moment.

Figure 5.10

Kamea Flipgrid response on Day 1 (voiceover was also used)



Kamea's block-coding abilities were very advanced compared to others, and she really enjoyed experimenting with the code. She often engaged in tinkering and experimenting, as she confirms in the above figure. Kamea's learning, her excitement when it came time to build, tinker, and experiment, and her appreciation for the novel experiences of using new tools is reflective of Papert's constructionist theory. She valued novelty, often citing how much she liked the variety and newness of the AI tools and activities we did during Camp. At the end of camp, Kamea wrote, "I liked the different websites we used. They helped me understand the different steps and coding needed to program A.I." She does not provide specific examples of the websites, but she often updated her progress via chat citing that they were "cool" or "fun" activities. Interestingly, Kamea mentioned at the end of camp that she wished she had the opportunity to do more coding activities like the FaceLock code, in which she used her favourite singer's picture to open the screen of a digital phone. This was an activity where she had the opportunity to tinker with the code while also infusing her personality (e.g., her favourite singer). Being able to integrate aspects of her personal interests perhaps made the activity more "fun", which has been noted a motivator in coding, especially for girls (Corneliussen & Prøitz, 2016). Kamea was the only participant, other than Daniel, who referenced the FaceLock activity specifically.

5.6 Summary of Findings

The section above highlighted insightful results of analysis and offered case studies as a closer look into the inner workings of individual campers over the course of the week. A summary of the main findings is presented below. They are organized into the four themes identified in the data, Redefining Personal Definitions of Artificial Intelligence, Engaging in Critical Thinking, *Meehaneeto*, and *Building Technical Competency through Coding*. The four themes have been explored in detail in the prior sections of Chapter 5 but have been concisely summarized below to highlight key findings from the study.

5.6.1 Redefining Personal Definitions of Artificial Intelligence

1. Most participants had a limited understanding of AI at the outset of this camp and their personal definitions showed little nuance or balance.
2. At the beginning of camp, more participants defined AI in terms of their ability to help humans.
3. Throughout the course of the camp, participants were mostly concerned with personal and human relationships as well as the real-world applications of AI.
4. Critical thinking could potentially be a driving force for instigating the redefinition of personal definitions of AI, as personal definitions often referred to or were moulded by critical discussions in camp.
5. At the end of camp, participants still defined AI in terms of helping humans, but had much more nuance within their definitions.
6. At the end of camp, most participants' perceptions of AI shifted from "robot-centric" to "everyday AI".

5.6.2 Engaging in Critical Thinking

1. Most participants, at some point, displayed modest to high levels of critical and balanced thinking while engaging with the content, displayed in statements that referred to social, environmental, or physical implications of AI.
2. When engaging in critical thinking, campers often made connections between AI and their own technology use.
3. When re-evaluating students' perceptions surrounding the relationship between artificial intelligence and humans, most participants showed higher levels of complexity, nuance, and critical thought when compared to their first responses.

5.6.3 Meehaneeto

1. *Meehaneeto* provided a way for campers to reveal their interpretations of technology and AI and draw parallels between the events in the graphic novel and their real lives through discussion- and design fiction.
2. Most students cited *Meehaneeto* as a helpful tool in understanding the role AI plays in our society.

5.6.4 Building Technical Competency

1. Most participants had none to limited block coding experience, except Kiara and Kamea, campers who had rated themselves highly in terms of proficiency.

2. In post-camp interviews, all participants cited block-coding projects as a boon to their understanding of artificial intelligence.
3. At the end of camp, most students successfully completed a scaffolded block-coding AI challenge that included creating virtual AI assistants, despite the majority of campers having no block-coding experience at all prior to camp.
4. Most students enjoyed learning new tools and were engaged in the block-coding and AI-based challenges, but it remained difficult to gauge the extent of their work due to the restraints of the online environment.
5. Participants with strong skills in technical competency also showed the most improvement in terms of building a personal definition of AI, suggesting that the two proposed domains of AI literacy are less separate entities and more of a feedback relationship.

Chapter 6

Discussion

6.1 Overview

This discussion will elaborate on the significance of the findings in the last section. The purpose of this chapter is to expound on the findings via thorough examination and dissection supported by relevant literature. To further contextualize the findings and offer interpretation, the discussion is grouped into the overarching themes that emerged from the final round of data analysis, which were previously presented in the findings section. The purpose of this study was to uncover the ways in which youth conceptualize AI and to investigate the shifts in thinking that occurred over the course of a five-day virtual camp focusing on a more holistic approach to AIL, one that emphasizes both critical thinking and technical competency. The present study was guided by the following research questions:

- What shifts in thinking surrounding AI occurred over the course of the camp?
- What design elements of the camp contributed to the shifts in thinking of participants?

These questions were designed to shed light on youth's preconceived notions of AI, to illuminate common or popular ways youth engage with AI (or believe they engage with AI), and to pinpoint effective tools and technologies to support youth's technical understanding and critical thinking around AI. The ultimate goal of this camp was to provide campers with the opportunity to learn about the field of ethical AI and to develop technical competency to better understand the "how" of AI. These two facets of AIL are not often blended to achieve a holistic or comprehensive picture of AI for youth.

6.2 Building Personal Definitions of Artificial Intelligence

AI is a relevant and growing topic in classrooms, yet the area of AI literacy is still underdeveloped in terms of building appropriate supports and curricula from which to teach students (Xhou et al., 2009). Most North American youth have some interaction with AI, but often fail to realize what and when these interactions take place (Forsyth et al., 2021; Hasse et al., 2019). As such, it was requisite to the camp's design to provide participants with opportunity to explore realistic manifestations of "everyday" AI, which seems to have succeeded. At the beginning of camp, during a pre-survey, participants were asked to provide a description about what AI meant to them personally. These definitions were collected and compared to post-definitions provided by participants during semi-structured interviews on the last day of camp. The process of re-defining personal definitions of artificial intelligence was a trend shown throughout the course of camp. Hassan's comment, " I used to think AI were just robots and stuff and realized they can be in computers and a ton of other stuff too. You can see it in phones, movies, ovens, etc." is reminiscent of previous work (cited above) that found youth often do not hold realistic views of AI and subsequently have trouble identifying the instances they interact with AI. He then went on to comment, "All technology isn't just a moving robot -- it can be in your phone or something and it doesn't have to be walking and talking."

The findings of the present research suggest that over the course of the camp, one of the most pronounced shifts in thinking over the course of the camp seemed to be the redefinition of AI. Prior to the content on the first day, campers filled out a pre-survey so researchers could gather a baseline understanding of where each individual camper stood in terms of understanding of AI, notions of AI, perceptions of human-AI relationships, and their personal definitions or descriptions of AI. At the end of camp, each camper participated in a post-interview in which they were asked again to provide their personal definition of AI. Most campers had different definitions compared to the start of camp, with the majority of post-definitions showing more balance (e.g., referring to the positive and negatives of AI or evaluating the ways AI can manifest in society), complexity (e.g., more instances demonstrating a deeper understanding of the role of AI), or nuance (e.g., displaying more flexible thinking).   of the camp was dedicated to discussion and meaning-making, paired with more technical challenges within the scope of digital constructionism, to expose them to both dimensions of AI Literacy. Regarding **Table 5.1**, which provides coded responses to the presurvey question, "How do YOU define artificial intelligence?", Armin had a sophisticated response, noting that he believes artificial intelligence to be a simulation created to directly mimic human intelligence and Daniel simply stated, "Technology, robots, phones". This may be due to typical portrayals of AI in the media, which is often physical, humanoid, and independently intelligent. He showed significant growth in his personal definitions of AI. At the end of camp, Daniel's definition of AI displayed much more nuance and critical thinking: "AI is something that you will be able to control and mostly uses technology to learn or recognize a human's voice, face or something humans usually do. Yes [there are concerns with using AI].” Daniel’s response is a far-cry from the “technology, robots, phones” that he provided at the outset of camp. Daniel does include “technology” as a way to describe the mechanics or technical dimension of AI. As AI Camp had large components of coding and “behind-the-scenes” AI activities, Although Armin’s response was sophisticated, not all AI, and certainly not many of the commonplace AI applications used day-to-day are created to simulate human intelligence nor are all AI applications physical robots (although campers did not specifically refer to “robots” as physical).

One particularly interesting response was provided by Ami, who wrote: “I define artificial intelligence as something that is mysterious and far away from me. It's something to do with technology and people always say that one day it could replace humans.” On one hand, Ami’s thinking shows that she conceptualizes AI as something mysterious and “far away” yet acknowledges that it is something in her everyday life. This may show a limited understanding of the manifestations of AI in common apps and tools. None of these responses are necessarily wrong; they all demonstrate at least limited understanding of AI (the definition of which varies depending on context and individual). The campers did seem to build on their definitions from the pre-survey throughout camp,

When participants were asked during the post-camp interviews what AI means to them individually, Armin offered a sophisticated response, noting that he believes artificial intelligence to be a simulation created to directly mimic human intelligence. This may be due to typical portrayals of AI in media. Although the response was sophisticated, not all AI, and certainly not many of the commonplace AI applications used day-to-day are created to simulate human intelligence nor are all AI applications physical robots (although campers did not specifically refer to "robots" as physical). This is a shift from the "friendly helper" theme of his first answer. The goal of the camp was not to eliminate the "friendly helper" as the archetype of AI, as youth do possess AI applications that are helpful and used with the intent to ease the burden of everyday tasks, but rather to illuminate that AI is not invulnerable to faults, bias, or data and privacy breaches. In fact, in order to fully grasp the scope of everyday AI applications, a significant part of learning should be dedicated to the common or seemingly mundane uses of AI coupled with the largely untouched conversations surrounding ethics, in order to lay a foundation of ethical AI for their future learning. Despite this, Armin's answer showed a development in the relationship he perceives to exist between AI and humans, shifting from something created to help humans to something created to mimic humans. Armin responded, "Camp made me realize that we humans are surrounded by A.I.- It doesn't have to be complex". Which is a departure from some of his earlier sentiments. This is a promising revelation, because one of the overarching beliefs that participants entered camp with was that AI was something removed from their everyday lives, except in the benign form of popular apps such as Netflix, Siri, and YouTube, or robotics. Most students cited that they believed algorithms and AI are best when they are complex - Complexity allows less room for errors when following instructions. Though it is difficult to continually prompt or even follow-up with campers' thinking when recording videos, while in chat, or while engaged in a project, most of the conversations and discussions were interspersed with many additional questions from the facilitators or researchers, to allow the participants to consider their positions and beliefs and expound on them. For Flipgrid, though it was a useful tool in assessing participant thinking and conceptualizations of camp, it did not allow for conversation or a two-way dialogue with facilitator/researcher and camper which may have helped bolster their thinking, as AI is a complex and novel topic for most participants. Despite this, Flipgrid proved to be useful when evaluating independent thinking.

Another stand-out participant was Kamea; her progress through camp was steady and consistently participatory. She was engaged from the beginning, offering her opinions and ideas in the chat box. However, even so, it was difficult for her to share her screen or to capture a complete picture of what was happening on the other end of the screen. As mentioned previously, her initial response when asked to list three things that come to mind when thinking of AI was "cool, smart, fun". A follow up question on the pre-survey asked, "Thinking of the answers you recorded in response to the previous question, do you think these are realistic representations of A.I.? Why or why not?", to which Kamea responded, "Yes. Robots are cool and fun, and A.I is smart". Though her coding and technical skills began strong and remained strong, her critical thinking and her personal definition of AI improved drastically over the course of the camp.

During post-interviews, it was clear that there was some foundation for ethical and realistic AI laid during camp. Many campers did mention AI as being more than just robots, indicating there was some degree of success in promoting, even subconsciously, thinking about this. However, during the interviews, it took prompting and/or time for many campers to cite any ethical implications they saw related to AI, and when they did, they were mostly concerned with physical implications and bias. Despite this, the activities, which were designed to be constructivist in nature, and the discussions, seemed to help lay the groundwork for future ethical AI education.

6.3 Engaging in Critical Thinking about AI

The discussions about *Meehaneeto* and AI often embodied features resembling the Socratic Method, a pedagogical strategy used to unveil students' personal beliefs about a subject through repeated questioning or prompting from the teacher (Conor, n.d.). This method naturally presented itself without planning; students were reluctant to follow up on their initial answers to a question without facilitators seeking additional information and input which spurred a favourable environment for incorporating elements of Socratic questioning and inquiry. This seemed to promote critical thinking in students, as most of their insights on ethical, social, environmental, and physical implications surrounding AI occurred after questioning. In section 5.2.2, the campers' responses when asked about examples of AI are provided. Armin came to camp with a seemingly complex understanding of AI, citing that the daily ways he uses technology are "social media, JWA, and smart devices. His "JWA" response (Jurassic World Alive, a video game) is particularly interesting because it demonstrates a level of understanding that games, something present in many youths' lives, are programmed and interacted with by way of AI. This is something imperative to help youth understand because games can be a very present force in adolescents' daily life. There were some particularly interesting answers to this question, including Armin's. One camper, Hassan, also demonstrated a more balanced view of how AI influences his daily life – When asked about how he personally uses AI, Hassan expressed an awareness of how his technology may take away from his unplugged activities, saying: "Instead of going outside or reading book I would play on my phone". This demonstrates some level of understanding that AI has the ability to alter human action in perhaps undesirable ways or in ways that promote disconnection from the world and the individual.

At the beginning of camp, many participants at the beginning of camp seemed to hold a common misconception, or conflation, that robots are synonymous with AI (see **Table 5.1**). Six of eight participants responded with "robots" in some capacity. Though this is by no means incorrect (i.e., robots do rely on AI and are a valid example), the overrepresentation of robots in initial perceptions of AI demonstrates a narrow view of what AI typically looks like. On the second day, campers were asked about the pros and cons of the internet from their own perspectives - The answers, though anonymous, showed varied perceptions. These answers can have particular attention paid to them as they were generated very early in the camp and supplied in response to a minds-on (before much information was given to campers). The Jamboard ideas then likely represent campers' genuine and pre-existing notions of the pros and cons of the internet and the advent of AI. Surprisingly, there were more perceived downfalls than benefits to the internet, but a commonly cited benefit related to the ease of access of information. This may be because campers interact with Google and search engines quite frequently (according to their pre-surveys). It is very interesting that campers, all of whom were under the age 15, cited information access as a pro despite perhaps never having experienced an alternative (e.g., not unfettered internet and information access), so this may be a reference to a video we watched that referenced life pre-internet. Armin's response to the question posed by the facilitator on day 2 revealed that he was engaging in critical thinking - He noted that Panopteeto may be viewed as dangerous because it, at its core, is technology, and technology can be programmed "wrong". This may be referring to AI bias or perhaps alludes to issues of privacy and data. Or, because Panopteeto is a hulking and intimidating figure, Armin may be perceiving that it wields physical power that when combined with faulty, unregulated, or irresponsible hardware, can be a dangerous combination.

Armin was a camper who remained consistent throughout camp. He brought a moderate level of knowledge surrounding AI and also possessed strong critical thinking skills. He was a camper who demonstrated critical thinking consistently throughout the camp and was seemingly eager to participate in discussions that seemed to engage critical thinking processes. The question, "Where do you think we will be [with regards to AI and technology] in 50 years?" was met with Armin's response, "either a wasteland because of pollution or just full of technology." This was quite interesting as it demonstrates two lines of thinking about the future: one doomed and one fully integrated with AI and technology (though he did not clarify whether the latter option he provided was meant to be positive or negative). Armin's opinion was balanced and more critical than others' who provided answers. Interestingly, Armin's opinion was the only one that considered the impact of AI outside of humans. His response acknowledges the planetary change that may be caused by misuse of AI, as well as acknowledges, or seems to acknowledge, societal change that may occur.

As camp progressed, instances in which campers analyzed their own relationship with AI in critical contexts emerged. For example, Hassan reflected on his own personal relationship to technology, stating:

> We spend a ton of time on electronics and stuff and I'm realizing that we spend way more time on electronics than going outside or something. AI "kind of" controls our behaviour

> because sometimes I would think of going outside and then my friend calls me and he wants to play a video game so I never end up going outside.

This reflection shows some degree of critical thinking and considers how he, in the present, is impacted by AI. This sentiment aligns with critical theory of technology, a pillar of the theoretical framework enacted in this research. Hassan, in this sentiment, muses that technology and/or videogames impact his relationship to the outdoors and social relationships. His use of the term "controls" is telling and denotes that he may believe he possesses a lack of agency in the choice between engaging with technology or not. This may speak to a personal high degree of motivation to play videogames, but also sheds light on how Hassan, and perhaps other youth, feel powerless or less of an agent when it comes to using technology. However, it appears that Hassan sees videogames as a form of social engagement, and going outside may not allow for the same social opportunities.

It may be that engaging in critical thinking around AI is a prominent driver in redefining AI with more complexity, balance, and nuance. To expound, having a wider critical "bank" from which to draw may allow for an individual to select more relevant information when describing or conceptualizing AI, and will result in a deeper understanding of AI with more knowledge from which to draw. Moreover, it seems even beginning to expose students to critical discussions around AI and technology help them build their own meaning and make their own connections and conclusions, as many of the ideas produced over the course of the camp were not explicitly focused on. Instead, campers seemed to engage in their own meaning-making tasks through critical discussion. This can be supported by research on the topic of meaning-making that suggests meaning-making, though facilitated by educational experiences, is a personal and internal process (Ignelzi, 2000; Kegan, 1982).

6.4 *Meehaneeto* as Design Fiction

Meehaneeto, the graphic novel, was a very present theme in student thinking, especially as it related to using it as a lens through which to view their own lives and society. *Meehaneeto* provided participants with an avenue to consider how technology and AI affected the characters' lives, which promoted their thinking when drawing parallels to their personal experiences with AI. Using *Meehaneeto* as a thematic anchor was a strong component in the success of AI Adventure. It both engaged participants while transforming difficult and abstract concepts related to ethical AI into an easily understandable narrative that in turn helped participants' critical and complex thinking skills through meaning-making. Narrative-based learning, or story-based learning, has been shown to promote meaning-making in students (Pantaleo, 2017). Although both narrative-based learning and discussion-based learning were not expected to be perspectives that emerged from the data, both of these frameworks have solidified a place in the current research and results. Design fiction, an element of this study's framework, is a way of imagining alternative futures and landscapes through imagination and speculation, and it often emphasizes critical thinking (Bleecker, 2009).

Further, using graphic novels or allegory for AI in our lives, like *Meehaneeto*, proved to be a useful tool that promoted critical thinking. *Meehaneeto* was an engaging medium for the campers to think about the parallels between the characters and themselves. Although *Meehaneeto* features a dystopian landscape, the themes within the graphic novel can be mirrored in our modern societies and our speculative futures. *Meehaneeto* was a tool that encouraged speculative and imaginative thinking through design fiction while also highlighting similarities between the novel and real-world contexts. Many campers echoed these sentiments in their post-interviews, citing *Meehaneeto* as an avenue that allowed them to understand character motivations and also helped them understand abstract concepts surrounding human-machine interaction and relationships. *Meehaneeto* drove the development of critical literacy through narrative-based learning. Critical literacy, as defined by EduGAINS (n.d.), "refers to students critically analyzing and evaluating the meaning of text as it relates to issues of equity, power, and social justice to inform a critical stance, response and/or action." Critical literacy is a part of the broader term, critical thinking, and also includes the ability to dissect character point-of-views based on contexts (cultural, political, lived experiences), and make meaning from texts (Ministry of Education, n.d.). *Meehaneeto* was a valuable avenue to explore critical literacy and design fiction thinking, and in turn, helped supply participants with more contextualized and nuanced opinions, which they used to engage in critical thinking and ultimately supported a fuller "reservoir" of personal meanings, ideas, and perspectives surrounding AI from which to form their post-camp definition of AI. Hassan wrote the following of *Meehaneeto,* "Meehaneeto made me realize that we spend a lot of time on AIs and on our devices and stuff". *Meehaneeto* in camp primarily worked in one of two ways: to draw parallels to their own lives and to extend their thinking into future realities. *Meehaneeto* provided participants with an opportunity to draw parallels between their current lives and the character lives, as supported by Ami's musing on it, "There are a lot of scenes that are related to our daily life and our discussions on it helped me to understand others' thoughts." Not only did Ami find some sort of linkage between *Meehaneeto* and her own life, but she also noted the discussions around it helped understand the perspectives and ideas of her peers. Some took these parallels a step further, using the parallels in *Meehaneeto* and extending them to some of the more futuristic aspects of the novel and applying them to a possible future for ourselves, such as Armin, writing, "AI impacts our daily life more and more every day as we build new technology and become dependent on AI to assist us, AI is almost always needed to do daily things". Design fiction, thought often only as a tool to be wielded in the design process, was more so used as a window into speculative futures by campers.

6.5 Building Technical Competency through Coding

The camp had the feature of Scratch and AI-based activities to build technical competency, so that students would understand the principles discussed in camp and also gain technical knowledge to further develop their AIL. Digital constructionist activities focus on building and

Interestingly, those who were strong block-coders seemed to develop a more nuanced understanding of AI. Perhaps knowledge of coding or the "back-end" of AI (even rudimentary-level knowledge) provides additional context and deeper understanding of realistic and potential uses of AI. As an example, a student who had absolutely no understanding of the *how* of AI would likely have a more difficult time conceptualizing the way AI can be used. The relationship between technical competency (the *how*) and critical thinking may be described, then, as reciprocal: technical competency allows for more informed instances of critical thinking. Similarly, because some participants equated AI with robots, it may seem that coming to understand that AI is not always complex could be indicative that participants' perceptions of what AI fundamentally is has also changed.

The present study also reflects the theoretical framework of Digital Constructionism used to underpin the camp. Kamea's learning, for example, her excitement when it came time to build, tinker, and experiment, and her appreciation for the novel experiences of using new tools is reflective of Papert's constructionist theory. In constructionist theory, the individual learner is most engaged and learns best when they "construct artifacts that can be shared and probed to the world" (Xerou et al., 2016). Tinkering and experimenting were often cited as factors that helped participant learning, with Armin writing, "My main strategy for overcoming challenging was just to play around with the programs a bit", with Zohan adding onto his sentiment, "Trial and error, and you have to look at things from a different angle to find out what is wrong." What Zohan describes is reminiscent of the processes involved with tinkering and debugging. According to Code.org, debugging is an essential part of learning to code as it involves practicing a number of skills that are involved with understanding different block functions and relationships. Scratch was included in this study as the nature of block-coding lends itself perfectly to the process of experimentation. Armin had this to say about Scratch, "Scratch because I like doing things hands-on and trying something new." Interestingly, he equated Scratch to something hands-on, despite being a digital activity. Digital contructionism would stipulate this too: even digital artefact creation involves situated cognition and making. Coding activities that allow for choice, creativity, and community are effective conduits to fun and motivation while coding. As Bers (2020) writes, "The 'playground vs. playpen' metaphor provides a way to understand the kind of developmentally appropriate experiences that new technologies, such as programming languages, can promote: problem solving, imagination, cognitive challenges, social interactions, motor skills development, emotional exploration, and making different choices" (p. 33). It is no wonder why participants, who, collectively, had very limited experience with Scratch and coding, found such motivation and enjoyment from the new and exciting activities that engaged both AI and making as these are much more akin to a playground than a playpen.

6.6 Study Limitations

Although there were some results in terms of students' shifts in thinking, there were various limitations that, should this study be considered for replication in the future, should be addressed. At the end of each camp day, the facilitators stayed online in the Google Meet room, and after saying goodbye to campers, discussed the challenges and successes encountered through the day. During one of these meetings, one facilitator noted that, "three hours is a short time for such big topics". Three hours a day is a particularly relevant time constraint to note due to the depth and scope of what was covered in the camp. The three-hour day also hindered substantial time spent on team-building exercises. The majority of students were naturally reserved, with both researchers and facilitators finding it difficult in certain instances to even draw out answers in the chat box. Despite beginning each day with a "How are you feeling?" prompt and an introduction, it may have been more beneficial to ask more personal or preference-based prompts, so participants could see others' interests and make peer connections. With COVID-19 and the shutdown of schools, participants likely would have been in virtual contexts in the prior months pre-summer

2021. Communication and collaboration in virtual spaces may not be the preference of students or this may be a skill outside of face-to-face communication that has not had a chance to develop. This could add a layer of discomfort when interacting in an unfamiliar setting (i.e., AI Adventure camp) with unknown people (i.e., other campers, facilitators, and researchers). These considerations were further amplified by the time constraints – Three hours per day (totalling 15 hours over the course of the week) was a limited amount of time for what the research hoped to achieve. Developing the camp, it was imperative that AI-based tasks and conversations took priority. Additional time spent engaged in low-stakes team-building games or activities may have been beneficial to both participants and researchers, as there were high levels of reluctance to share or engage with facilitators or peers. The vulnerability required in sharing and engaging was perhaps the largest barrier to collecting robust and complete data for each participant. As it stands, data could only be collected from participants who elected to engage with camp facilitators and peers. This left much to be desired in terms of data. It is challenging reading students' progress in a traditional classroom, and it is certainly more challenging reading student progress in an entirely virtual environment. In a virtual environment, students need to actively (and often publicly) share their work whereas in the classroom, a teacher can simply glance over a student's shoulder to see progress or have students hand their work in at the end of a period. Being in an entirely virtual camp with campers who were unfamiliar with each other and often, the content presented a level of vulnerability that the camp dynamic was unable to overcome. Even with encouragement, students often neglected to share their screens or even take screenshots to document what they were working on in a more private manner. In a similar vein, it was a challenge to enforce participatory components of the camp that were included to increase the robustness of data quality and quantity. For instance, FlipGrid reflections were completed near the end of camp as a daily reflection. It was difficult to regulate who was completing these FlipGrids, despite daily reminders. On average, only four participants (approximately half) completed the daily FlipGrids, with engagement dropping off around mid-week.

The use of chatbox as the prevalent form of communication was also a challenge upon analysis. There were varying levels of literacy when typing and left more ambiguity in the meaning of the sentence; because campers were socially hesitant, asking for clarification on mic or in the chatbox was not often effective. This leaves much interpretation in the hands of the researcher – many participants had spelling or grammar errors, omitted or added words that clouded meaning, and would not elaborate when prompted. Should participants feel more at ease or socially comfortable with other campers and the facilitators, it may have been easier to attain participation in screen-sharing, on-mic conversations, and more overall engagement when completing activities.

Moreover, another limitation was the range of levels of experience in block-coding. Instead of having participants work on large-scale projects during the latter half of the day, it may have been more beneficial to have participants engage in something more open-ended and imaginative. For instance, some participants had trouble understanding Day 5's larger task of building an AI assistant. This activity was chosen because researchers and facilitators agreed it would leave room for participants to add or remove features and generally "tinker" with the block-code, remixing it to create a more personalized AI assistant. However, because most participants came to camp with limited block-coding experience, it may have been more effective and also beneficial to have something more imaginative that involved Scratch. Participants could, instead, have designed their definition of a society where AI was developed and integrated to their personal ideals, essentially design fiction integration in Scratch. Overall, it was difficult to manage the varying levels of experience in block-coding and providing sufficient support and challenge to meet all participant needs.

One important note is that critical feminist theory was a guiding piece of the theoretical framework used to inform and guide the present research. Given the review of the literature, feminist theory was included as it was thought that it may have helped to inform data and analysis and reveal gender-based findings. Despite this, the data collected did not allow for analysis of this kind and therefore yielded limited evidence that there were any differences between the experiences of participants based on gender. In order to examine this more thoroughly, more directed conversations based on personal experiences, intersectionality, and STEM identity (and the factors that contributed to or inhibited growth in STEM identity) may have been needed during camp with more focused questions. Intersectionality is a nuanced topic that had a place in the design of the camp – AI Adventure Camp touched on topics such as race, gender, and religion and the ways these things interact with individual experiences with AI. Unfortunately, results directly related to personal reflections on intersectionality did not come to pass. It was likely taken for granted that these findings would naturally emerge regardless of environment, activities, and conversations. These topics can be deeply personal, and students may have not wanted to engage in conversation with people they did not know. As researchers and facilitators, our primary aim was to ensure campers had comfortable and fun experiences during camp and we chose not to put pressure on conversations that were not naturally arising, especially ones that can come with a host of potentially negative emotions in a relatively unfamiliar setting. However, even though there were no findings aligned with critical feminist theory, girls did make up the majority of those who "dropped out" over the course of the camp. This is particularly troubling, as it may speak to the larger cultural trends in those who hold interest in the realm of artificial intelligence. All participants in the pre-survey noted some degree of personal interest in AI and despite this, those who stopped coming each day or logged off at some point during the camp day tended to be girls. As per the prior literature review, one potential fortification for digital camps going forward is to target a more specific population – in this case, girls. Having an environment specifically tailored to girls and their individual needs for appealing and safe learning environments would perhaps be more beneficial to girls with interests in tech. The final task, though most complex in technical skill, was still rather close-ended. In retrospect, the final task or capstone project may have been better developed to be something in which participants could impose their own perspectives and learning of AI that they had grown over the course of the camp. These limitations can help develop future iterations of camp that will likely yield more robust and streamlined data.

6.7 Educational Implications

Artificial intelligence is a relevant and important topic all across the globe. Classrooms are an integral part of culture and society, and in an era where information overload is the norm in our day-to-day and AI is ubiquitous, classrooms are often the place in which important critical discussions surrounding equity, justice, and ethics are relevant to our modern contexts (Thomas, 2019). The current research contributes to the field of youth AI education through examining their experiences within a 5-day virtual camp with a focus on ethical implications in society. This in itself is valuable as the research sheds some light on common conceptions of AI prior to the camp, gains insight into the drivers of the growth in thinking and offers participants' perspectives on AI post-camp. The data presented in the findings can be used to tailor more effective interventions and programs designed to enhance youth's understanding and thinking around the ethics of AI and the role AI plays in everyday life. Moreover, as social justice, equity, and AI bias play roles in the ethical implications of AI, the participants in this camp may walk away more prepared to handle these topics in a more sustained and in-depth setting (i.e., a classroom).

Further, this study offers a more integrated model of AI Literacy (based on the two dimensions presented in earlier sections); one in which critical thinking and technical competency hold a reciprocal relationship. This model can be considered when designing more holistic AIL experiences for youth as critical thinking (which includes matters such as AI in society, implications of AI, etc.) and technical competency (which includes matters such as coding, robotics, etc.) are often taught as insular subjects. As technical competency informs critical thinking and vice-versa, this model may be used to inform more comprehensive AIL activities in which critical thinking and technical skill are emphasized in the learning.

The point in which we all stand in history ensures that the relationship between AI and humans is one that cannot, at least right now, be untangled: AI is surprisingly a very human process in which individual people are at the "starting line" of development. It is humans that generate datasets for machine learning, humans who provide feedback to algorithms, and humans who put AI applications into practice. The humanness of AI can be its downfall when considering the ethical implications of using AI in our everyday lives. AI has unfathomable potential to better planet Earth when developed ethically and responsibly, with these big-picture ideas in mind, and Marcus and Davis (2019) believe that one of the key reasons AI is currently limited in its positive practical applications is trust. In *Rebooting AI: Building Artificial Intelligence We Can Trust,* the authors espouse the importance of understanding the limitations of current AI and working to build flexible and ethical programs. The authors infuse hope into their writing, noting that the unethical and oppressive AI systems in place today are avoidable, writing, "We are confident that many of these technical problems can be solved – but not through current techniques. Just because temporary AI is driven slavishly by the data without any real understanding of the ethical values programmers and system designers might wish to follow doesn't mean that all AI in the future has to be vulnerable to the same problems." (loc 688). Although the technology is not quite there and a paradigm shift is required to set this reimagination of ethical AI into gear, the significance of educating youth about AIL that blends the two dimensions together so that they can engage with AI responsibly and, perhaps one day, champion ethical AI initiatives in the workforce. The findings from this research can help future programs fine-tune and build effective curricula for a more holistic framework for AIL.

6.8 Future Research

The findings and limitations of the research lend insight that may inform future iterations of AI Adventure Camp and research surrounding AI literacy in youth. With regard to the design elements of the camp, here are a few considerations that may benefit participant learning going forward. Future iterations of this camp may see more shifts in critical thinking if presented with a more open-ended capstone project than the one in the first iteration. The limitations reported in section 6.3 serve as a basis from which to improve and reassess. Many participants reported that *Meehaneeto* was helpful to their learning and supported their growth in perspective. It is therefore recommended that future iterations of AI Adventure Camp continue to use *Meehaneeto* as a thematic anchor. Emphasizing the graphic novel format and developing open-ended tasks that allow participants to create their own AI-based graphic novel may be a worthwhile consideration for capstone projects in future AI camps. Graphic novel creation would allow students to convey their thoughts and feelings towards a topic more explicitly than completing or modifying a pre-made task such as the virtual assistant task students worked toward completing on Day 5. Further, having students create products that draw from their own knowledge, perceptions, and ideas of AI would be more telling for analysis and would allow researchers to glean a clearer picture of personal student beliefs.

Another under-examined area of study is teacher AI Literacy. Teachers are responsible for introducing and often developing ethics-forward AI Literacy programming due to the lack of pre-made resources suitable for all classrooms. There is a limited scope as to what a week-long summer camp such as AI Adventure can accomplish. OST programs, especially short-term ones like camps, can be an excellent avenue to kickstart the skills and conversations that are needed to facilitate AIL. However, sustained AI education is important to ensure that youth have long-term opportunities for learning. Therefore, teacher education should be prioritized alongside student education, so that OST programs can supplement classroom instruction and material. AIL, as defined in this paper (i.e., having an equal focus on technical competency and critical thinking) becoming an integral part of classroom curricula will be paramount to helping shape ethical AI users who understand both the computational and mathematical principles underlying AI and how to engage and consider AI with scrutiny and a critical perspective. Further, as campers valued *Meehaneeto* as a design fiction and used it as a window into a speculative future, it would certainly be fascinating to extend the research and explore the effects of making and design fiction (designing or creating their own) on the development of critical thinking and supporting ethical perspectives of AI.

As mentioned, teacher education is important when considering future directions of AIL. However, with teacher education comes more comprehensive and reflective programming of AIL to use for classroom instruction. To ensure quality AIL education, future research should also strive to uncover the mechanisms behind the interrelationship between the two proposed dimensions of AIL. Focusing on the framework of AIL is a critical step in producing a unified standard of AI education for youth and ensures that the programming is comprehensive and optimized to promote critical thinking, as AI programming in classrooms often solely focuses on technical competencies.

Chapter 7

Conclusions

7.1 Overview

The following section outlines the conclusions and recommendations for future research and iterations of AI Adventure Camp. These conclusions are drawn from the analysis presented in previous sections as well as researcher observations and post-camp day conversations.

AI Adventure Camp was a five-day (3 hours per day) camp focused on building technical competency and critical thinking skills as they relate to AI in the hopes of promoting AI literacy. AI Adventure Camp was novel programming for the STEAM-3D Maker Lab, which offers an array of STEAM-related camps, workshops, and professional development sessions to students and teachers alike. AI Adventure accrued a total of eight participants and was hosted via Google Meet.

AI influences much of the information we intake daily and plays a significant role in our society, functioning as both a personal helper and an efficient, data-crunching computer. However, AI is often locked in a cycle of AI bias, beginning with the human at the outset of development. These biases in data can manifest in the product outcome and reinforce culturally or socially embedded stereotypes, which often present at the expense of marginalized populations and groups. AI bias, for instance, has ensured that hand dryers or the braking mechanism within self-driving cars do not respond to deeper skin tones, that facial recognition does not identify those wearing head coverings, that women's resumes are systemically filtered out from applicant pools, and that

AI image detection misidentify or do not recognize deeper skin tones in pictures (Najibi, 2020). Because youth are a large stakeholder in AI usage, the present camp developed content that addressed these ethical implications of AI with youth participants. The ultimate aim of the camp was two-fold: First, to ask and answer the question, "What were the shifts in thinking that occurred over the course of the camp?" and second, to ask and answer the question, "What were the design elements/content elements that supported these shifts in thinking?". The first question was asked to illuminate the perceptions that youth hold about AI – What are their perceptions of AI? Are they accurate? Are they based in media? What do they know about the ethics of AI? How did their thinking change or remain the same during camp? The answers to questions such as these were marked as important, as they can provide insight into the relationship between AI and youth, which can, in turn, provide insight into the shifts in thinking that occurred. The second question addresses why or how the shifts in thinking occur – Understanding this, and what helps or hinders youth's thinking surrounding AI can inform future iterations of not only this camp but curricula or programming for AI literacy. The prominent design elements included the virtual environment, discussions, breakout groups for coding and AI-based building projects, and the use of *Meehaneeto* and its narrative as a daily thematic anchor.

The central research question addressed shifts in thinking that occurred throughout the camp: What perceptions of AI do youth hold? How does youth define AI's relationship with humans? With themselves? Did these notions evolve over the course of the camp? These shifts in thinking were the central research question because understanding the conceptions (or misconceptions) that youth hold toward AI can target the gaps in AI literacy. This can perhaps result in more effective, comprehensive AI literacy program development that integrates both technical competencies and critical thinking skills. Technology is not neutral – we have an ever-increasingly connected society that calls for equity, understanding, and collaboration between not only AI and humans, but humans and other humans. The biases that exist within the algorithms that influence so much of our daily lives are not neutral. These biases are not always intentional, but instead reflect the historical biases that are harboured deeply within societies. The bias can often stem from the lack of diversity that is present within the tech world. The absence of neutrality in technology is a double-edged sword; technology can be a powerful tool to promote equity and knowledge if the development and wielding of it is both responsible and ethical. AI is making advancements in science, health, and overall improvements in day-to-day functions that would have been unimaginable a mere few decades ago. These biases manifest in our AI, and the algorithms and machine learning programs that are put into place can reinforce systemic barriers and be used as a tool for sustained oppression. It is critical that we call for Ethics-forward AI programming in schools for youth, to raise awareness of how AI can uphold oppressive systems and how they can use AI ethically and responsibly. The discussions in AI camp had a positive impact on participants, propelling their thinking in terms of *what* AI is to them and *how* it impacts our societies. Similarly, despite the overall lack of experience with both AI as a general concept and block-coding, participants were able to complete a series of block-coding challenges that grew more complex and self-directed. At the end of camp, most campers were able to successfully complete an "Smart Classroom" task, even incorporating the use of a camp-wide "meme" of Robert Downey Jr. Robert Downey Jr. had become a funny inside joke between campers, who often used his pictures to test or build AI models from. The spread of the Robert Downey Jr. meme suggests that, with time or more dedicated team-building effort, there may have been more sharing, conversation, and collaboration between campers. The camp environment was referenced as an effective way to build coding skills and an understanding of AI, because it was a dedicated three-hour time frame compared to classrooms, where it may be a topic of conversation for a few minutes every so often.

Youth are a very active group of AI users and in the United States, those aged 18-29 years old make up the majority of Instagram, TikTok, Twitch, Reddit, YouTube, and Snapchat users, all of which rely heavily on algorithms to deliver content (statista.com, 2022). Although coding has been implemented in the 2020 curricula revisions (Ministry of Education, 2020), the expectations are narrow, mostly focusing on mathematics and computational sciences. Though this is an important aspect of AI, there is still a prominent gap in which the ethical implications of AI are left unaddressed in the curriculum. The implementation of lessons regarding the ethical and social dimensions of AI are often developed by third party organizations, such as Common Sense Media, and teachers can pick and choose content at their own discretion. However, teachers may not be comfortable with AI content, especially when it comes to integrating it in ways outside of the curriculum. To achieve AI literacy in classrooms, though it is important to engage and support comprehensive AI programming (i.e., technical and social dimensions of AI), teachers should also receive the same outreach.

Critical thinking surrounding AI could perhaps be a driving force for redefinition, as it exposes youth to realistic perspectives of AI. Most of the shifts in thinking around AI were shaped by critical discussions and activities performed in camp, and then used in their definitions and cited in their perceptions of AI. Further, participants who showed the largest shifts in thinking and who had the most sophisticated understanding of concepts surrounding AI, also possessed higher levels of block-coding proficiencies and overall technical competencies regarding AI. This is intuitive: to have a nuanced definition of AI, it should be informed by a high level of AIL. AIL has two proposed dimensions, one that refers to technical competency and one that refers to critical thinking competencies. A balanced, sophisticated, and nuanced understanding of AI will naturally encompass both of these domains in some capacity. And critical thinking is surely utilized while engaged in problem-solving associated with challenges faced. In fact, critical thinking and problem-solving are inextricably linked (Butterworth & Thwaites, 2013). As an exploratory study, there was not enough data to fully identify the particular tools or drivers for either dimension and future research may explore this in the future.

Revisiting the purported dimensions of AI literacy presented in the literature review, it was suggested that these dimensions (D1 and D2) can be accurately reflected in a table.

Table 7.1

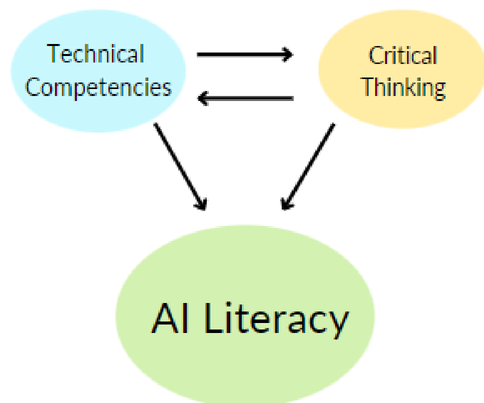
The two disparate dimensions of AIL

Artificial Intelligence Literacy	
Technical Competencies	**Critical Thinking**
Using computer and technology-based skills to accomplish goals and obtaining strong working knowledge of principles of computer science or using technology. Examples: • Meeting coding expectations in the Ontario Curriculum • Developing understanding of programming, machine learning, math, and computer science principles • Opportunities to "make" and "tinker" with robotics • Using coding applications such as Scratch	Examining AI as both a theory and concept in relation to the role it plays in societies. • Examining how algorithms can be biased, affect daily life, and influence media consumption • Investigating the social dimensions and ethics of AI, including equity, privacy/security, and who is responsible for the development and regulation of AI • Social, environmental, and physical implications of AI • Exploring critical digital citizenship

A simplified but more reciprocal version of an AIL model is presented below, revised from the literature review. There are many intersecting factors at play, but as this study was exploratory, the actual interplays between specific aspects of each dimension of AIL are still yet to be completely understood. However, from what was seen in the data, stronger coders and those who entered camp with more advanced technical competency ended up, interestingly, with more nuanced definitions and more instances where they were engaged in critical discussion and thinking. Technical competency, that is, understanding coding, mathematics, and computational thinking can possibly help inform critical thinking by allowing an individual to more deeply understand the limits and abilities of a completed ICT or AI application. Therefore, a simple yet more refined model of AIL as defined in this paper is presented below.

Figure 7.1

AIL model showcasing D1 and D2 reciprocity



It is intuitive that both aspects of AI Adventure, the technical challenges and the critical discussions, would offer participants more information from which to shape their personal definitions and perceptions of AI and those engaging in both may have more nuanced or balanced definitions of AI at the end of camp.). This is something modelled in Kamea and Armin, who not only were strong in technical competency had impressive definitions of block-coding and had prominent instances of critical thinking. In their post-interviews, they noticeably drew from their learnings at camp as well and used critical discussions to inform their thinking. There is perhaps a relationship between their technical skill and their critical thinking with each domain providing the other additional context and knowledge when it came time to defining AI. For example, if Kamea is an effective block-coder and has successfully completed block-coding and AI projects, when it comes time to draw a conclusion of what AI is to her, she now possesses the knowledge of the basic underlying principles of AI, such as code and programming, from which to draw on. Her technical context of AI can help inform realistic representations of AI: Her definition is informed by her block-coding and AI knowledge, and she can then form a more sophisticated opinion of AI grounded in situated knowledge that takes her from a robot or media-influenced mindset of AI to something moulded by her own experiences. Similarly, in this example, block-coding and technical competency may help Kamea conceive of ethical and social impacts of AI as she now has a developing understanding of realistic AI manifestations and more frame of reference when considering AI bias and unethical algorithms. On the other hand, her instances of critical thinking can help her technical competency: it can support her when working through problems, using tech tools, utilizing different perspectives, thinking divergently, participating in decision-making and problem-solving, and seeing the big picture of the AI tool she is engaging with. When Kamea then comes up with her definition at the end of camp, she now possesses a wider reservoir of knowledge that contains her personal experience of AI, which is informed by her technical knowledge and experience in addition to her critical thinking in relation to AI. Therefore, this proposed process may underscore the interplay between the two dimensions of AI literacy that, when they are presented as a whole, might result in payoff greater than when presenting them separately. As this is an exploratory study there is not enough data to accurately present a completed model of these factors. For instance, it is relatively unknown what activities within technical competency and critical thinking modulate or provide feedback to one another although it appears that there is a reciprocal relationship between the dimensions of AI literacy, rather than being separate domains that are developed independently and largely unrelated.

7.2 Summary of Conclusions

A summarized version of the conclusions from this study are presented below, highlighting significant insights gathered from findings and informed by relevant literature.

1. As our world becomes increasingly connected, it is more important than ever to support AI Literacy both inside and outside of the classroom.
2. AI Literacy, as it is defined in this paper, is critical for developing nuanced understanding and critical examinations of AI in society and promotes scientific and mathematical understanding of the mechanisms underlying AI.
3. There may be a reciprocal relationship between the two proposed dimensions of AIL (D1 Technical Competency, D2 Critical Thinking).
4. A five-day camp for three hours a day yielded positive results for developing AIL but it is inconclusive whether these results will be long-lasting or continue to evolve.
5. It is critical to implement ethics-forward AI literacy programming that encompasses and braids the dimensions of AI Literacy (Technical Competency and Critical Thinking).
6. Going forward, teacher perceptions of AI and comfortability with implementation of AI programming should be addressed to ensure sustained AI Literacy.

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Appendices

Appendix A. Advertising Materials

A.1 Camp Advertising Poster

A.2 Camp Advertising Instagram/Social Media Post

Appendix B. Pre-Camp Forms

B.1 Online Registration Form

AI Adventure Virtual Camp Registration Form

The following information is necessary for our records, to ensure the safety of all campers, and to provide a positive experience for children, staff, and volunteers. All information provided is confidential. This camp will run Monday, July 19th to Friday, July 23rd, 2021 from 12:00 PM - 3:00 PM and is open to students in grades 6-8.
Please visit our lab website for more information: http://janettehughes.ca/lab/programs/virtual-summer-camps-2021/

Contact Information
Please provide your child's name, address and DOB. Please also provide the name and all appropriate contact information for at least one parent/guardian.

Child's Name (First & last):

Address:
Date of Birth:

Parent/Legal Guardian #1 Name [First & last]:

Parent/Guardian #1 [Contact phone number]:

Parent/Guardian #2 Name [First & Last]:

Parent/Guardian #2 [Contact phone number]:

Confidential medical history:

Medical/Behavioural/Emotional Issues, Disabilities, or Allergies [if none, please indicate "N/A"]:

Emergency Contact Information

Emergency Contact Name [First & Last]

Emergency Contact [Phone Number]

How much experience does the registering camper have with block coding?

- I have no experience with block coding
- I have limited experience with block coding
- I have some experience with block coding
- I have a good amount of experience with block coding
- I have lots of experience with block coding

Camp Code of Conduct

The Camp has "Rules of Conduct" that all students, staff, and volunteers follow that so that everyone can have a fun and safe program experience. Campers who cannot consistently follow camp rules will be removed from camp. Please take the time to go through this code of conduct with your child/children and have them check off all boxes to indicate they understand and agree to the camp rules.

1. I will be respectful to others in the camp (including the camp facilitators).
    - I agree
2. I will keep my microphone muted unless it is my turn to speak.
    - I agree

3. I will use positive, appropriate language in the chat box.
    - I agree
4. I will not send spam to the chat box.
    - I agree

B.2 Form of Informed Consent

Please read the following letter of information. Registration in this free research camp means all attendees are required to participate in the research component (more details on what this entails can be found below). By reading this information letter, selecting your agreement and participation levels and clicking the "submit" button found at the end of the letter, you are both submitting your child's enrolment in the camp and you are also agreeing to the research component of the camp.

Letter of Information – Parents

We are teachers and researchers at Ontario Tech University (OTU). We are interested in how youth perceive, define, and critically think about artificial intelligence, as well as the shifts in student thinking that occur over the course of a 5 day AI camp.

We are asking for your consent for your child to participate in this research camp, led by Canada Research Chair, Dr. Janette Hughes. If you do provide consent, your child will also be asked for their assent (below) before participating in this study. Assent means expressing approval or saying yes to participating.

This project includes the use of a digital environment containing various apps, websites and resources that students and parents can access. These virtual tools will help with the teaching and learning of various subjects, like AI development, programming, multimodal content creation, and global skills and competencies, like critical thinking. The students will be asked to access these various online tools which will include programs like Scratch and Powtoon. The camp is based on the graphic novel, Meehaneeto, written by Dr. Janette Hughes. Participants will dive into questions about cybersecurity, cyberethics, and navigating a digital landscape ethically and responsibly.

Collection of Information:

Information will be collected at various times during the project. We will gather information in the following ways:

• We will ask your child to complete an questionnaire on the first day
• We will observe your child during the sessions and take notes about how they participate(s) in the sessions, how the students interact with one another and the facilitators, what kinds of things they create during the sessions, comments they make and/or ideas shared
• We would like to take screencaps of work they complete in the sessions for reflection and analysis purposes
• We would like to video-record and/or audio record your child for the same reasons as above and during the interviews at the end of the study. Interview questions can be shared with you on request.

A summary of the research tools and time allotted for each tool for the students include:

• Pre-study questionnaire: ~15 minutes
• Five, three-hour sessions (over five days): 15 hours
• Post-study semi-structured interviews:~10 minutes

Findings from this project may be published in journals and presented at conferences.

Voluntary Participation and Withdrawal:

Your child may withdraw from the study at any time without penalty.

Your child can choose not to answer specific questions. If, during any of the above-described activities, your child decide(s) not to participate, s/he/they can end involvement in the activity by approaching the researcher and indicating that s/he/they wish(es) to withdraw from the study.

Your child may communicate refusal verbally or non-verbally (i.e. in the chatbox).

Confidentiality:

The information your child provides will not be stored with personal identifiers, nor will your child be identified in any recorded or published comments.

The transcripts of the sessions, as well as any other data collected, will be stored securely at OTU under the researchers' supervision and will be destroyed after five years. By consenting to participate, you do not waive any legal rights or recourse.

Participation Benefits and Risks:

Potential benefits for participation in this study for your child includes:

Learning new digital tools; learning about the ethics and implications of AI; learning about the development and regulations of AI; learning about how to navigate AI responsibly and safely; gaining opportunities to practice block programming skills; developing critical thinking skills.

Potential risks for students include: feeling pressure to share or embarrassment from sharing work.
Risks will be dealt with in the following ways: Facilitators will explain to students that they have the right to pass when it comes time to sharing their work.

Clicking the "Submit" button below on the consent form indicates that you have read this letter, understand its contents, and authorize the participation of your child in this research project.

Please note that your child's assent is also required. Parent and student consent is required to participate in this study.

If you have questions about this project, feel free to contact project lead Dr. Janette Hughes (905.721.8668 ext. 2875 / janette.hughes@OntarioTechU.ca) or the OTU Research Ethics and Compliance Officer, who can provide answers to pertinent questions about the research participants' rights (compliance@uoit.ca (905) 721-8668, ext. 3693).

Thank you for considering participation in this research study.

Dr. Janette Hughes, UOIT

I have read the Letter of Information for the above research study. I understand the purpose of the research and my questions have been answered to my satisfaction.I understand that I have the right to withdraw my child from the study at any time and that declination from participating in the project will not have any negative consequences for me or my child. I also understand that my child has the right to withdraw from the study at any time and that the information collected is for educational/research purposes only. By clicking the "Submit" button below, I give consent to participate in the research study. For the purposes of research, I give consent for my child to be recorded:

- Audio Only
- Audio/Video
- Neither Audio nor Video

Letter of Information – Students

We are teachers and researchers at Ontario Tech University (OTU).

We would like to study how students perceive and critically think about artificial intelligence and its ethical implications.

We would like to know if you would like to participate in our research project. In the project, you'll be using a variety of online tools and games to learn about how AI is developed and regulated, while also engaging in activities that allow you to build and test your own AI programs through block programming languages and other multimedia projects.

You will learn about topics like the development of AI, cyberethics, cybersecurity, and how to navigate a digital world safely and responsibly.

Collection of Information:

If you agree to participate, we will:

• ask you to complete a questionnaire before the study begins (15 minutes)
• watch what you learn and create while you use the apps and programs (15 hours)
• take screenshots of your work
• video-record and/or audio record you while you work
• interview you at the end of the project to see what you learned and whether your perceptions, definitions, and thinking around AI have changed (10
minutes)

Voluntary Participation and Withdrawal:

If you do choose to participate, you can choose to stop participating at any point during the study. You just need to tell the facilitator that you don't want to participate any more. You can also choose not to do some of the research parts (like
the interviews). You would just need to tell the researcher that you don't want to be interviewed.

Confidentiality:

Also, just know that your identity will be protected at all times. We won't share your images or work with anyone without making sure it is anonymous (which means there would be no way of knowing it was you/your work).

Participation Benefits and Risks:

If you do choose to participate, you will learn lots of new information about AI and you will get a chance to practice your block coding skills. You'll learn about cyberethics and security, and have many opportunities to develop important critical thinking skills. You may be asked to share your work, but you will always have the right to pass.

By clicking the boxes below on the assent form, it means that you understand what the study is about and what you will be asked to do. It also means you would like to participate.

If you have questions about this project, you can ask your parent(s)/guardian(s) before the study begins or you can ask anyone on the research team once the project has started.

Please check off all boxes Assent Form - Students / I agree that...

- It's my choice to participate in this research camp
- I give permission for my work to be collected and used for research purposes
- I give permission to be either audio or video recorded for the interview (my parents will indicate this on the consent form)
- I give permission to be recorded during research activities.
- I understand that all information collected (my work, any recordings) will not include my real name. Only the researchers will have access to any identifying information and no identifying information will be used in any research reports.

Appendix C. Data Collection Tools

C.1 Pre-Survey Form

1. In what ways do you use technology at home?
2. In what ways do you use technology at school?
3. What are your favourite learning apps, programs and/or websites?

4. What do you find difficult about school or learning?

5. What types of things do you enjoy learning about?

6. What are your favourite ways to learn about these things?

7. How would YOU define artificial intelligence (this does not need to be a Google definition, but rather what you think artificial intelligence is)?

8. List at least three things that come to mind when you think of A.I.

9. Thinking of the answers you recorded in response to the previous question, do you think these are realistic representations of A.I.? Why or why not?

10. What are some examples of A.I. that you have previously interacted with?

11. How might A.I. impact your daily life?

12. What are some positive and negative impacts of A.I. on society?

13. How would you describe the relationship between humans and A.I.? 14. What interests you most about A.I.? 15. What do you specifically want to know about A.I. that you don't already know?

C.2 Flipgrid Reflection Prompts

Day 1	What did you learn about AI? What surprised you? How did you feel working with Scratch? How would you improve your program in the future?
Day 2	Did you run into any problems building your classifier? How did you solve them? If you could build any classifier, what would YOU build one for and why?
Day 3	What might happen if AI is built without a code of ethics? What do you think is necessary in a code of ethics?

Day 4	What would be some things at home that you would like would like have a smart assistant for? Would this be useful, why or why not?

C.3 Semi-structured Interview Questions

1. Overall, what was your experience like at camp this week? For example, you could choose to share one thing you liked and one thing you didn't like as much about the camp this week? 2. What were some successes and challenges you encountered at camp this week? 3. In general, how did the camp help you better understand concepts related to Artificial Intelligence? i. What activities (i.e. coding activities, discussion-based activities) helped you better understand A.I.? ii. How did the graphic novel, *Meehaneeto*, help you better understand issues surrounding A.I.?

4. How would you now define A.I.?

5. What are three examples you can think of that would be considered A.I.?

6. How do you now think A.I. impacts your daily life?

7. How do you now think A.I. impacts society?

i. How would you now describe the relationship between humans and A.I.?

8. Just out of curiosity, why did you sign up for this A.I. camp?

9. Overall, what is your biggest take-away from camp this week (in general and about A.I., specifically)?

C.4 Post-Interview Questions

1. Overall, what was your experience like at camp this week? For example, you could choose to share one thing you liked and one thing you didn't like as much about the camp this week?

2. What were some successes and challenges you encountered at camp this week?

    i. Why do you think you were successful here...

ii. How did you overcome the challenges you encountered?

3. In general, how did the camp help you better understand concepts related to Artificial Intelligence?

i. What activities (i.e. coding activities, discussion-based activities) helped you better understand A.I.?

ii. How did the graphic novel, Meehaneeto, help you better understand issues surrounding A.I.?

4. How would you now define A.I.?

5. What are three examples you can think of that would be considered A.I.?

6. How do you now think A.I. impacts your daily life?

7. How do you now think A.I. impacts society?

i. How would you now describe the relationship between humans and A.I.?

8. Just out of curiosity, why did you sign up for this A.I. camp?

9. Overall, what is your biggest take-away from camp this week (in general and about A.I., specifically)?

Appendix D. Coding Scheme

D.1 Codes related to Redefining Defining Artificial Intelligence

Main Theme	Category	Code	Description of Code	Example

Redefining Personal Definitions of Artificial Intelligenc e	Human-AI Integration	Simulation of Human Intelligence	Statements describing AI as a simulation or mimicry of human intelligence.	"I would define artificial intelligence as a simulation/duplicate of human intelligence in machines that are meant to mimic humans."
		Human-Machine Hybrids	Statements describing machine-human integration or hybrids.	"All humans will be half robot! lol"
	Human Relationships to AI	Personal Interests	Statements describing personal interests.	"I only read about AI if it's also related to something I like, for example biodiversity or space." "I want an AI intelligence system like Jarvis in Iron Man."
		Helpfulness (Society) Helpfulness (Themselves)	Statements describing AI as a helpful tool to humans/a tool for betterment of society. Statements describing AI as a helpful	"AI teaches a computer or a program to do something on its own to help humans or do a task." "AI can help humans in their everyday life and AI can acknowledge more people that humans might not even know." "I would want an AI to do my homework for me."

			tool for their own personal interests.	
		Media (Movies)	Statements that refer to familiar AI representations in movies and media	"I want an AI intelligence system like Jarvis in Iron Man." "That video reminded me of Wall-E."
	Ethical Considerations in AI Development	AI Bias (Programming)	Statements surrounding bias, equity, and fairness in AI or machine learning data sets.	"The AI has to be programmed by someone and if that someone knows about university and colleges decides the person gets accepted, then yes it is fair because they probably put their opinion in the programming." "I think AI is accurate if it's programmed based on proof and it's unfair if it's just random or based on bias." [In a Flipgrid]: "What might happen if AI is built without a code of ethics is: The AI or program might be biased."
		Algorithms	Statements or work that describes or notices algorithms.	"We would need more pictures in a dataset to ensure that the algorithm is more accurate." "I think a complex algorithm is better

				because it has more instructions and if it misses a step it will change the result.”
	Applications of AI	Danger (Humans) Danger (Environment)	Statements related to AI being dangerous or threatening to humans.	“Because in her mind, Petateeto is dangerous because it's technology and could be programmed wrong.” (Humans)
		Security and Privacy Concerns	Statements on the topic of security and/or privacy and the ways AI helps or hinders our security.	“We have lots of security cameras everywhere.” “A.I helps humans do tasks but some things might not work out. like accounts can get hacked.” “Security might be a problem. When there is an accident there will be news online instantly and when there is a case of COVID 19, the health agency website or the news will report the case instantly. Humans can control AI with coding and face recognization so that they can replace in a factory, car wash, and more.”

		AI in Daily Life	Awareness of AI in everyday life	"Used to think AI were just robots and stuff and realized they can be in computers and a ton of other stuff too. Now I can see it is in phones, movies, ovens, etc."
		Robotics (Applications)	Statements relating robotics directly to AI or vice versa.	"There are robots that work for farmers and water their vegetables."
	Mechanical Aspects of AI	Unassisted Intelligence	Statements of AI not requiring human will to perform its task	"AI is a computer or program that thinks by itself to do something."
		Robotics (Mechanics)	Mentions of the mechanical components of robots, not necessarily the applications in society	"AI works because of microchips."

D.2 Codes Related to Engaging in Critical Thinking

Main Theme	Category	Code	Description of Code	Example
Engaging in Critical Thinking	Ethical Implications of AI Use on Society	Environmental Implications	Statements that support awareness of environmental impacts of AI in the present or future.	When asked where we will be with AI in 50 years, Armin responded: "Either a waste land because of

				pollution or just full of tech.”
		Physical Implications	Statements that support awareness of physical impacts of AI in the present or future.	“If you use it [AlterEgo] too much, it could affect your ears.” “It can damage your eyes if you look at the screen for a long time.”
		Social Implications	Statements that support awareness of social impacts of AI in the present or future.	“Negative: Less socializing and gratitude for others, job impacts…”
		Equity and Equality	Statements that refer to equity and equality within the context of AI and technology.	“AI needs to be built with a code of ethics because everyone deserves equal rights.” “AI can be unfair to some people and not others.”
		AI Bias (Applications)	Awareness of AI bias and how it may manifest.	When asked what would happen if AI was built without a code of ethics, Kamea responded: “It might only work for some people.”
		Security and Privacy Concerns	Statements on the topic of security and/or privacy and the ways AI helps or hinders our security.	“We have lots of security cameras everywhere.” “A.I helps humans do tasks but some things might not work out.

				like accounts can get hacked.” “Security might be a problem. When there is accident there will be news online instantly and when there is a case of COVID 19, the health agency website or the news will report the case instantly. Humans can control AI with coding and face recognization so that they can replace in a factory, car wash, and more.”
		Evaluation	Statements describing both the positive and negative aspects of AI.	“Either a waste land because of pollution or just full of tech.” “During camp, I learned that A.I can be biased but there are ways that you can program it to not be biased.”
		Reasoning	Statements that display the process of reasoning concerning AI.	“Maybe it did that because it was broken.”
	AI Influencing Personal Behaviour	Loss of Human Agency	Statements that denote feelings that integration may or is resulting in loss of human agency	“AI will be doing our jobs in 50 years.” “AI may do everything for us!”

		Personal Implications	Statements of awareness that AI or technology modifies participants' personal behaviour.	"They "kind of" control our behaviour because sometimes I would think of going outside and then my friend calls me and he wants to play a video game so I never end up going outside."

D.3 Codes Related to Building Technical Competencies

Main Theme	Category	Code	Description of Code	Example(s)
Building Technical Competencies in AI Literacy through Coding	Personal Interest in Applications	Novelty	Evidence of excitement or elevated interest due to new tools, games, applications	"Teachable Machine worked most of the time, so that was fun. It was fun to train the different things to recognize all the different stuff. Had never done anything like that before. "
		Teachable Machine	Statements mentioning Teachable Machine	"Teachable Machine worked most of the time, so that was fun. It was fun to train the different things to recognize

				all the different stuff. Had never done anything like that before. “
		Scratch applications	Statements mentioning Scratch	“I liked camp because I learnt something new about A.I and coding with scratch and how it helps the world. There wasn't anything I didn't like.”
		Engagement	Statements that relate to interest or enjoyment while working on projects	[When Kamea was working on a coding project in Scratch]: “It’s working! Cool!” “I added another class for falcons and also used a picture of a cat that was already in my classifier yet it says it looks least like a cat and more like a falcon and domestic rat!”
	Digital Constructionism	Experimenting	Accounts and statements or work that shows experimentation or non-prescriptive “tinkering” with coding or adding additional challenges to the activity.	When programming the AI assistant, Kamea finished early, writing in the chatbox: “I think I’m going to try to change the colours”.

				"It was fun to experiment and change the code."
	Problem-Solving	Facing Challenges	Evidence of campers facing challenges while engaged in digital constructionist activities.	"I'm confused, where do you get the Scratch page and when you do, what do you do?"
		Persevering through Challenge	Statements relating to the process of overcoming or persevering through challenges faced during digital constructivist activities.	"I explored and tried several times on how to train a machine before it worked." "My machine learning algorithm had trouble detecting at first but when I added more images it worked better." "Mine had trouble detecting the "nothing" category at first, but when I deleted some images from the "paper" section, it worked better." "It didn't work but after some help it started working."
	Social Learning	Collaboration	Evidence of peer-to-peer or peer-to-facilitator	When Facilitator 1 shared a tutorial

			collaboration.	on the paper/plastic/card board recycler, there was an error. Armin and Zohan both immediately came on the mic to share why they thought this error occurred (even though there was no prompting from any of the facilitators asking them to share).
		Sharing Work	Screens or products shared in breakout groups or whole group periods.	Peter shared a Robert Downey Jr. classifier he built using Teachable Machine with the whole group. Zohan shared his screen to showcase the Scratch program he was building.

D.4 Codes related to *Meehaneeto*

Main Theme	Category	Code	Description	Example
Meehaneeto as a Tool for	Narrative-Based Learning	Negative Parallels	Statements that draw parallels	"Everyone is on technology."

Understanding			from *Meehaneeto* to negative occurrences in daily life.	"Everyone is always looking at their devices."
		Positive Parallels	Statements that draw parallels from *Meehaneeto* to positive occurrences in daily life.	When asked about similarities between a scene from *Meehaneeto* in which technology and society had been integrated and our own 21st century society, Kamea responded "Robots doing gardening." referring to AgBots we discussed earlier in the week. "There are a lot of scenes in *Meehaneeto* that are related to our daily life." "The *Mehaneeto* graphic novel help me to understand that how the AI can help in our daily life."
		Speculative Futures	Statements that indicate *Meehaneeto* as a tool for speculation	During a discussion following *Meehaneeto*, Armin wrote, "AI impacts our daily life more and more every day as we build new

				technology and become dependent on AI to assist us, AI is almost always needed to do daily things”
	Discussion-Based Learning	Discussion	Statements that refer to the daily discussions we had in regard to *Meehaneeto*	“Our discussions on *Meehaneeto* helped me understand others' thoughts.