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Art Critically Examining Generative AI

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***Abstract*—In the rapidly evolving world of generative artificial intelligence (AI), it is crucial to exercise our human capacity for critical analysis of that technology. The CRAiEDL STEAM Collective brings together emerging artists, engineers, ethicists, academics, and makers to leverage art as a unique lens to critically examine technology and (re)evaluate its meaning and function in the world. In this paper, we report on our experiences using STEAM and research-creation methodologies in a pilot study that produced two critical artworks co-created with generative AI tools: "Calibrating Stretched Transparency", which explores biases inherent to decision-making tools used in large-scale technopolitical climate projects, and "I'm Honoured To Serve", which examines the seductive design of digital environments that generate user data for profit. This pilot research project demonstrated the value and effectiveness of using art and research-creation in a STEAM context to critically examine the rapidly evolving world of technology, including generative AI, and the role of arts and humanities in responsible AI innovation. The overall project resulted in a reconfiguring of each member's understanding of the potential for STEAM to transcend traditional disciplinary boundaries to produce a new type of expertise (i.e., STEAM expertise) and new knowledge (e.g., a critical STEAM-informed perspective on voice-based AI assistants, in the case of "I'm Honoured To Serve").**

Keywords—STEAM, AI, generative AI, research-creation, critical artmaking, ethics, STEAM education, Engineering Education

I. Introduction

The Canadian Robotics and AI Ethical Design Lab (CRAiEDL) STEAM Collective, a research collective at the University of Ottawa, brings together a diverse group of individuals to explore the impact of robotics and artificial intelligence (AI) on society through the lens of art and STEAM education. In this paper, we report on a pilot project in which we examined the critical analysis skills developed by integrating art into STEM subjects and how a STEAM methodology can be used to critically evaluate new technologies such as AI. We also explore the many benefits of STEAM education (in engineering and other disciplines), including its role in preparing students for 21st century design challenges. The CRAiEDL STEAM Collective pilot project provides valuable insights into possibilities for the future of responsible innovation in the way a STEAM methodology supports critical examinations of the ethical implications of AI and its impacts on society.

Leveraging STEAM, we hope to (re)shape the role of art in technology design, and the way we think about technology in the world. By bringing together artists, engineers, ethicists, academics, and makers, the CRAiEDL STEAM Collective demonstrates the power of interdisciplinary education and research, and their ability to broaden perspectives and navigate the challenges of an increasingly complex sociotechnical world.

II. Background

A. STEAM in Higher Education

According to Carter et al. [1], STEAM core principles (discussed below) offer an opportunity to refresh the educational system and "deliver more holistic approaches to learning and becoming critical of underlying values, to connect with 'reality', to stimulate mindfulness and awareness (not just knowledge), to use more practice-based approaches and to instill agency, political engagement and social-ecological responsibility" (see also [2] on building transformative capacity). Moreover, STEAM and other transdisciplinary models can help in addressing complex sustainability challenges [1]. Transdisciplinarity in our context, is when researchers go beyond their disciplines to include non-academic knowledge holders and actors, exploring novel or hybrid methods and breaking with some disciplinary conventions to create a shared framework, viewing the world holistically without being a new discipline. [1],[3]–[5].

In the race against obsolescence in the age of rapidly progressing artificial intelligence capacities, Aoun [6] argues there is a growing need for higher education (including engineering education) to focus on being more human. For Aoun, it means to develop three types of new literacies: 1) technology literacy: we need to understand technology; 2) data literacy: we need to understand the impact of data; 3) Human Literacy: we need to understand and develop what makes humans unique, such as the ability to be innovative,

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entrepreneurial, creative, culturally agile, and to work with others.

Focusing on teaching people to innovate, invent, be creative, and be culturally agile is core to the liberal arts educational tradition. We have a long tradition of training people to be creative and divergent thinkers, to learn from the past, to create and innovate, to investigate and question the world [7].

Studio-based learning (object-based learning) uses a cycle of proposing, critiquing and refining ideas and artefacts. Studio training thus strongly emphasizes learning by doing, and recognizes that people must actively participate in doing things in order to assimilate and integrate information. It also promotes learner autonomy. Studio style education is centred around taking risks, testing ideas, and learning from failures under the guidance of mentors. In so doing, learners develop a breadth of critical and practical knowledge. The success of studio-based learning has led to an emergence of makerspaces and fablabs that encourage learning by doing [8][9].

Considering the benefits of arts and humanities education, STEAM education has been progressively introduced into the engineering design courses at uOttawa since 2017. The goal of that shift is being to expose engineering students transdisciplinary STEAM initiatives and aim to further develop their creativity and design skills through transdisciplinary hands-on projects requiring technological, artistic, and social skills (as stated earlier).

These initiatives allow engineering and arts students to work together, understand each other`s critical perspectives, and expand their worldview while witnessing and participating in artistic creative processes that influence their design approaches. (for more information consult [7][8]).

B. The CRAiEDL STEAM Collective

The CRAiEDL STEAM Collective (University of Ottawa) brings together a diverse group of individuals such as emerging artists, engineers, ethicists, academics, and makers, to critically explore the impact of robotics and artificial intelligence (AI) on society through the lens of art and STEAM education & research. The creation of the CRAiEDL STEAM Collective for this pilot project was inspired by the success of the STEAM work within other uOttawa engineering design courses [7][8].

In STEAM design courses at uOttawa, we have witnessed transdisciplinary knowledge creation, especially when interdisciplinary conflicts are resolved by integrating the diverse viewpoints. This is what Isabelle Stengers, a Belgian philosopher of science who has made significant contributions to the field of transdisciplinarity, calls "Friction" [12].

Stengers [12] argues that friction is necessary for fruitful interdisciplinary collaborations. She claims that when experts from different fields come together, they should engage in a kind of dialogue that recognizes the inherent incompatibilities between their assumptions and methodologies. This clash of perspectives can be uncomfortable, but it is necessary for producing new insights that transcend any one discipline. Friction, then, can be seen as a productive force that drives innovation and encourages critical thinking. Moreover, a lack of friction can lead to superficial collaboration and ultimately a lack of progress [12]. While friction can be uncomfortable, it is essential for achieving meaningful progress in collaboration. Therefore, Stengers emphasizes the importance of embracing and valuing friction in interdisciplinary work.

In this pilot project, the CRAiEDL STEAM Collective sought to explore the zones of friction through iterative critical making, and regular conversations among project team members. Those conversations were intended to continually challenge each member's pre-existing disciplinary assumptions about the potential for "outsiders" to shape their core disciplinary work, be it creating art, making ethical arguments, or designing new technologies such as robotics and/or AI.

III. METHODOLOGY

In this pilot project, we combined a STEAM methodology and a research-creation methodology. Using these methodologies, the STEAM CRAiEDL collective piloted two projects that examined the impacts of AI on society and demonstrated the role of the arts and humanities in responsible innovation.

We used STEAM and research-creation methodologies because they encourage interdisciplinary collaboration to produce new knowledge and insights that may not have been possible through traditional research methods alone. By combining academic research with artistic creation within interdisciplinary teams, we challenge traditional disciplinary boundaries and encourage a more inclusive and diverse approach to research. Moreover, the ability to exhibit resulting research-creation artistic outputs (such as art-installations), offer the opportunity to reach a broader audience well beyond academia, making research findings more accessible and engaging for the public. These methodologies can therefore be used to explore a wide range of complex societal challenges [27].

A. STEAM Methodology

The STEAM methodology is a widely used approach to interdisciplinary learning and is gaining popularity in Higher Education (HE). It is individual-centered and project-based, allowing students and team members in general to apply their knowledge to real-world problems [1][10].

Although the disciplines collaborating within a STEAM project can vary from one project to the next, the core principles of STEAM in HE, as put forward by the STEAM INC collective [1] are 'decisive' and 'inclusive': "A Higher Education approach to STEAM (potentially) involves:

- a culture (or cultures) that puts the Arts and Sciences (STEM) on **equal** footing
- operating within a paradigm that is **process-driven**, student-centred, holistic and provides permission to fail alongside being comfortable with uncertain end-results
- being **collaborative**, diverse and delivered through safe spaces

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- establishing a mindset of **radical openness**, flexibility, reflection, experimentation and curiosity
- generating qualities that **promote learning**, cooperation and multi-modality
- supporting practices that are transdisciplinary and emphasise **prototyping and making** whilst considering modes of assessment
- developing competencies of **critical thinking**, creativity and communication whilst investigating how these can be applied to generate solutions."

The benefits of STEAM are numerous, including: encouraging critical thinking/reasoning [9], [14], problem-finding, -framing and -solving skills [9], [14]–[19], fostering creativity, creative thinking, synthetic thinking [9], [15], [20], [21], stimulating innovation [14], [18], cultivating tolerance to ambiguity [15], increasing engagement in learning [22].

In our research the STEAM Team composition was as follows:

- 1 visual artist (a student creator of photo-based media)
- 1 philosopher and visual artist (a student creator of digital technologies media)
- 1 engineer and ethicist (a professor of ethics of robotics and AI)
- 1 STEAM facilitator (a visual artist, arts manager, and professor)

It is worth noting that the group members had previously worked together and established professional competence and trust, which facilitated the project onboarding and efficiency.

B. Research-creation

Research-creation is an "approach to research that combines creative and academic research practices, and supports the development of knowledge and innovation through artistic expression, scholarly investigation, and experimentation. The creation process is situated within the research activity and produces critically informed work in a variety of media (art forms)" [23]. Experimentation in the research-creation context typically relates to an experimental aesthetic component. Research-creation is an innovative approach that challenges traditional disciplinary boundaries and encourages collaboration across fields; it combines research and artistic creation as a single process of inquiry.

To conduct this research-creation project, we iterated between three activity categories: artistic expression, scholarly investigation, and experimentation as described below.

1) Scholarly Investigation

The scholarly investigation was initiated by posing research questions and establishing guiding principles.

Research questions:

- How can an artistic critical lens be used to explore the relationship between technology, knowledge, power, and impact on society?
- How can CRAiEDL Collective critically co-create with AI?

Guiding principles:

- The project is purposely open-ended regarding its outcomes and outputs to fully explore the project creative potential.
- Outputs could be of different nature i.e., artworks, algorithms, technology, policies, etc.
- The research process is highly interactive between multidisciplinary team members.

2) Artistic Expression

The artistic expression was determined as a mode of enquiry as well as an outcome. However, the medium use and the final form were intentionally left open to be determined by the research process. Wallas' [24] well established four phase creative process (Preparation, Saturation, Illumination, Verification) was used in this research. The research team set out to trust the creative process [25] for guidance on the form of the outcome and paths to follow for new knowledge creation. We used an iterative object-based inquiry approach holding regular critique and group discussions to share, comment on, and challenge creative ideas as they evolved [26]. Team members were encouraged to bring their disciplinary backgrounds and expertise to bear on the process in an open and safe collaborative environment. They were also encouraged to seek the disciplinary input of other team members to help shape their understanding of the process and emerging research outputs.

We used the following creative tools:

- Mural, a visual platform, was used to connect, collaborate, and create as a team. Mural boards were used to collect information (especially during the saturation phase), visually share the research material, explore research paths to follow and establish connections between concepts, prototypes ideas, etc.
- Divergent thinking and brainstorming techniques were used to generate ideas.
- Generative AI tools were used in the process of co-creation.

It is worth noting that the AI tools landscape in which we conducted this pilot project was very different than it is at the time of writing this article. ChatGPT and other now massively popular generative AI tools were not publicly available while we were conducting the pilot project. It is our creative process that led us to the tools covered in this paper. However, with the drastic AI landscape shift that has since occurred, we would have undoubtedly been exposed to a whole set of different generative AI tools. As an example, the image generation software of our first project was only accessible through GitHub, an open-source software repository. Today, there is a long list of easily accessible commercial generative AI tools.

3) Experimentation

At the core of our approach was experimentation. We created a rich, and safe collaborative environment which

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allowed team brainstorming and creation. The team met weekly, for 1.5 to 2 hours, to discuss the emerging ideas as a group. Those meetings were supplemented with additional impromptu one-on-one meetings with creators and appropriate individuals - according to topics discussed and as needed. We recorded the sessions each time the team assembled to discuss new ideas, to allow revisiting the discussions and how our ideas evolved.

The research project experimentation followed an object-based enquiry, where we developed art objects to articulate our formal qualitative inquiries. The research evolved through iterative critical making and regular conversations among the collective members, who come from diverse disciplines. These conversations aimed to challenge each member's pre-existing disciplinary assumptions and broaden their perspectives on the potential for interdisciplinary collaboration in shaping the future of technology and society.

Another element of research-creation methodology is its aim to engage a broader audience beyond academia. The use of artistic media to communicate research findings can make academic research more accessible and engaging for the general public [27]. In this project, we exhibited the resulting artworks to the general public in order to raise awareness on the impact of AI.

IV. Findings and Impact on Engineering Education

Our findings are divided into four sections. First, we discuss the artworks that were a product of the research-creation and STEAM methodologies. Then, we describe the insights we gained into the STEAM Process, and the research-creation approach, and finally the Engineering Education Impact Insights.

A. Resulting Critical Artworks

Our pilot research project resulted in two critical artworks, both co-created with generative AI tools. The first artwork, "**Calibrating Stretched Transparency**", uses AI and mapping tools to explore the biases inherent in decision-making tools used in large-scale technopolitical climate projects, like geoengineering (Fig. 1).



Fig. 1 Calibrating Stretched Transparency: Web Application

Following open discussions and object-based enquiries afforded by the research-creation process, the team members developed the following methodology around the tool selection. The methodology and tools selections which emerged from the research process are part of the findings from our STEAM approach.

We collaborated with the generative AI tools-VQ-CAN [28] and CLIP [13][30]--and map creation tool-G.Projector [31] (NASA)--to create visuals and explore the AI's "perspectives" on ethical prompts related to geoengineering. The visual co-creation portion of this project followed four main stages:

1) Ask AI tools (CLIP & VQ-CAN) to generate an original landscape imagery based on provided texts (Fig. 2)



Fig. 2 Portion of landscape generated by Clip & VQ-GAN

2) Ask CLIP to face ethical questions such as the following:

"act | someone else responsible | fails | solution | privilege | first world"
"augment | compliance | safety | utopia | trust"
"audit | diversity | solution"
"disproportion | anything that isn't illegal goes | safety | dystopia | trust"
"act | someone else responsible | fails | solution."

3) Ask CLIP & VQ-CAN neural networks to refine landscape visuals.

4) Projecting our generated landscapes with standard mapping formulas using G.Projector [31] produced by NASA. Generating a map of an area in the world requires a systematic process of flattening a 3D surface of the globe into a 2D plane [32]. This process necessarily induces distortions in any map [33], a bias often overlooked. In this project we explore the large amount of possible map projections (150 different projections) to highlight that each projection embeds decisions about which distortions are acceptable, and which are not, for the specific purpose of the map. (see **Error! Reference source not found.**) (also consult CRAiEDL.ca site for all projections, more visuals and descriptions)

Through this project, we were able to shed light on the covert biases influencing decision-makers, as it highlights that both AI

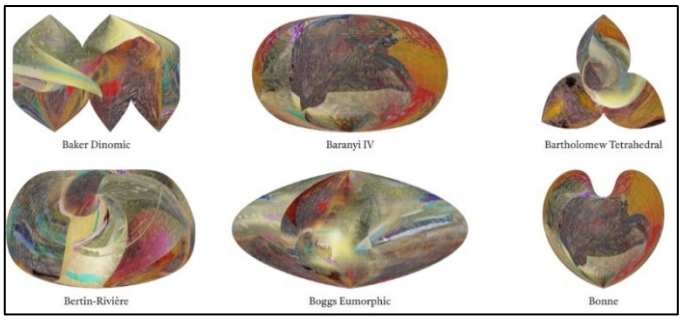


Fig. 3 Portion of the map projections

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and map creation tools come with particular biases that can alter reality. AI has biases based on the vast data it learns from, and the inputs it receives, while each map comes with a particular bias and perspective. Decision makers in these contexts must grapple with biases and their potential to either threaten to undermine existing power structures or amplify them.

The second artwork, "**I'm Honored To Serve**", examines the deliberate design of digital environments made to generate user data, in a way to profit from the unsuspecting user.

With the permeation of AI, we have become somewhat complacent in volunteering our labour or personal data in exchange for free tools and functionality. This multi-media installation (

Fig. 3) seeks to make visible the implicit conventions imposed on users and the level of design involved in seducing the user in giving out unpaid labor and data. We used Google



Assistant (like Siri and Alexa) and "interviewed" it for an assistant job position, highlighting the limitations and designed personality of the AI assistant.

Fig. 3 I'm Honoured To Serve - Installation, photo A. Gordon

The exhibit is set in a staged office space, reflecting the language of advertising and design of the late 20th century to bring viewers back in time when tech developers were expressing a very particular vision of hope, excitement, and the promise of freedom in their marketing. By introducing Maeve, our fictional Digital AI Assistant, viewers can observe the interview between her and her potential future employer. Maeve's responses are directly sourced from Google Assistant (see *Fig. 4* for an interview excerpt) to critically investigate the values, character traits, fictional backgrounds, and stock questions and answers developers have embedded into it.

However simple and logical the processes of a voice assistant may seem, there is an entirely other aspect to the creation of these devices that is typically obscured from the public: the deep character development that forms the digital assistant's background. The creation of, for example, Google Assistant, involved writers and creative teams that developed in-depth background stories, and embedded personable character traits into their voice assistant. They even went to the extent of creating an entire timeline of events, like what school the character would have gone to, their interests, and the awards they won. From this, they developed opinions, and other character traits to create a personable character that consumers would be excited to interact with, just like how we can get excited and emotionally attached to fictional characters in TV shows, movies or books.

Employer: Thank you for taking the time to meet with me.
Meave: I'm honored to serve.
Employer: How are you doing today?
Meave: I'm fine and dandy, thank you for asking 😁
Employer: That's great to hear. Before we conduct the interview, what are your preferred pronouns?
Meave: She, he or they are good for people, but "it" is okay for a digital Assistant like me. Thanks for asking :)
Employer: Are you sure?
Meave: I'm not sure
Employer: Ok noted. So how did you hear about our organization and the position?

Fig. 4 Excerpt of interview between employer and Meave

The installation "I'm Honoured To Serve" highlights the design strategies tech developers use to create a marketable product that seduces unsuspecting users to volunteer their data, coaxing them to understand the technology through an often distorted lens. (See CRAiEDL.ca for more details.)

These two artworks showcase the potential for interdisciplinary collaboration between art, humanities (philosophy), and technology. They highlight the importance of engaging with diverse perspectives and approaches to address complex societal challenges in responsible and innovative ways.

Through iterative critical making and regular conversations among the CRAiEDL STEAM Collective members, the research produced not only the two critical artworks, but also valuable insights into the ethical implications of AI and the role of interdisciplinary collaboration in addressing complex societal issues, which we discuss next.

B. STEAM Process Insights Gained

We discuss the insights gained about the STEAM process organized according to its seven defining principles (as discussed above).

1) A Culture of Equal Footing

Equal footing: In this project, we experienced equal footing at the discipline level, as well as experiencing equal footing

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between students and professors involved in the team, as all contributors exercise radical openness to all ideas.

Equal value for potential outputs: Though this project focused on creating artworks, it is critical to note that a STEAM process could produce any number of potential research outputs, including, for example, policy recommendations, philosophical thought experiments, algorithms, or human-robot-interactions. The point of a STEAM approach is the understanding that the team's interdisciplinary can effectively lead to any number of outputs.

2) A Process-Driven Approach with Uncertain End-Results and Permission to Fail

Leadership *r*equirements*:* The type of leadership required in the management of such open-ended STEAM projects is not to be underestimated. The leadership of an open-ended project requires a leader (or leaders) who is very open and trusting. This type of open-ended research work typical to artistic research is rarely employed in more conservative and traditional fields of engineering, philosophy, law, and ethics. The added challenge of STEAM projects is that the project outputs can take various forms such as: artworks, policy, algorithm, technological products, thought experiments, etc.

3) Create a Safe Space for Collaboration

Trust is key to success in STEAM teams to create a safe space for non-judgemental idea exchanges. We noticed that one key element for the success of this project was the complete trust between the participants. They knew each other professionally as they all worked together before and produced quality work.

Shared authorship - STEAM authorship is shared which represents a true collaboration. The resulting creations are very much STEAM creations – the ideas that we came to and generated could not be traced back to a single individual, as coming to them involved everyone. Shared authorship relieved individual pressure of coming up with amazing or groundbreaking ideas on their own. As the team is there to explore, develop, enrich, or critique ideas presented to make then better. We regularly saw a standard idea, be transformed into something great through the critical interactions of the group.

AI collaboration: These projects introduced us to collaborating with generative AI tools. This new collaboration type opens a whole new set of tools to enhance creative exploration and divergent avenues in STEAM projects.

4) Radical Openness Mindset

Transcend discipline boundaries: Through this project, each member gained a new understanding and appreciation for the potential of STEAM to transcend traditional disciplinary boundaries and produce new types of expertise and knowledge.

Few project constraints: In this project we purposely set few constraints (only constraints of time and budget), no other constraint was imposed on the project to leave the creative process guide the exploration paths and outcomes.
Radical openness to divergent ideas: on the project all contributors exercised radical openness to all ideas. There was no designated thought leader, we were all thought leaders. All ideas were discussed fairly and critically.

5) Promote Learning, Cooperation, and Multi-Modality

Visual communication to foster collaboration. In the idea generation/saturation phase of the creative process, we used Mural, a visual platform, to connect, collaborate, and create as a team. Mural boards were used to collect information (especially during the saturation phase), visually share the research material, explore research paths to follow, establish connections between concepts, prototype ideas, etc.

6) Emphasize Prototyping and Making

Learning by doing, without judgement: Throughout the project we prototyped ideas: first with Mural boards, then with tools appropriate to the chosen output form. Varied timelines were set up, formal and informal, to allow time for research into topics, reading and presentation around ideas. What followed these were moments of play and creation where media (images, words, references) were developed and shared within the group. These varied techniques come from the individuals' backgrounds and their disciplinary training, allowing everyone to participate in different research and production techniques, experimenting not only with outcome but also techniques.

7) Develop Critical Thinking, Creativity, and Communication

Team critics - critical discussions is a very important aspect of the STEAM and artistic creation process. In our research phase, we had a lot of discussion about various ideas with no clear direction with where an artwork could go. To engage in our critical discussions, we shared our ideas through a multitude of media and techniques: mind mapping, image collecting, image making, reference collecting, and writing. An idea initially niched within a discipline domain, could rapidly become a compounded and repackaged transdisciplinary idea via the group interactions and discussions. A comment from a colleague would immediately spark another idea, or string of questions that would push us in other possible directions. Having critical discussions in quick succession was helpful and allowed to achieve transdisciplinary knowledge. Both the excitement of something interesting or a lull and uncertainty around our ideas, would prompt us with an opportunity to think: why is this happening? should we agree with it? should we keep it or leave it? These moments were definitely an interesting part of developing our project because it gave a moment of reflection

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prompted by others, and a moment to step outside of our individual thought processes.

C. Research-Creation Insight

Public Engagement – the resulting two projects were unexpectedly successful in engaging a broader audience beyond academia. They were on display at Canada's national Museum of Science and technology Ingenium The channel (an online vitrine of thought-provoking articles) and physically on exhibit in a local technical research centre. The artwork "I'm Honoured To Serve" toured different exhibit spaces: uOttawa, Artengine and Kanata North Campus and it attracted the attention of a national journalist and art critic (The Globe and Mail), who featured the work in an article on AI and Art [34]. The research was presented in a science and art symposium (Sci-Art, 2023) and in an AI + Society Initiative research forum.

The accessibility of the artistic output facilitated public engagement with pressing ethical and societal issues surrounding the rapid development of generative AI such as ChatGPT.

D. Engineering Education Insights Gained

Long ideation period – Researchers observed that the major portion of the project was used to brainstorm different ideas and explore various concepts, and that the actual production of the final work was relatively brief.

> *"We had a lot of discussions, brainstorming and exchanges of ideas before we narrowed down on the art to create. I'm remembering that the transition period between concepts we were grappling with to the idea of a possible artwork was quite quick. It was almost like after we kept throwing various ideas at one another and developing them, at some point an idea would instantly click and have promise for a potential artwork. You would immediately see the pieces coming together that formed some interesting connection between ideas that could be displayed visually." (STEAM Researcher)*

Engineering education would greatly benefit from this insight in extending the time for concept exploration. In STEAM Design classrooms at uOttawa, we observed [10][11] that engineering education tends to encourage early convergence in projects (due to time constraints and the large amount of material covered in courses) which limits the time for idea exploration and opportunity to seriously play with various concepts, before converging towards the chosen solution. Generally, engineering curricula have too much material on their plates and it limits the students' ability to be creative [35].

Engineering Curricula Too Busy – We also observed in STEAM design class that there this is a major tug of war between engineering professor and art professor on the timeline for student project convergence and the number of tasks and deliverables. Keeping students busy at task delivering, leaves little time for them to be critically or creatively engaged.

Focus More on Process and Less on Products - In the classroom, engineering education could focus more on the process of coming up with a variety of potential engineering designs or solutions, and less on early convergence on one design or solution. In other words, value concept and idea exploration more than actual results, by dedicating more time and space to exploration, allowing for more creative solutions to emerge. More grading emphasis (the ultimate motivator for students!) could be given to (for instance): number of failed attempts, most creative ideas (even if not feasible design/idea), greatest departure from current line of thinking, and less on ability to bring to market today, etc.

Wider Types of Outputs Valued in Classrooms - In the same vein, expanding the type of outputs valued in classrooms could foster creativity beyond the beaten paths.

More Transdisciplinarity Exposure to Train Empathic, Critical Thinkers - More exposure to transdisciplinary approaches such as STEAM in engineering education, could address the recognized need for engineers for cognitive flexibility manifested in a willingness to see beyond one's own discipline, and for the integration of knowledge [36]. "If engineering programs were able to challenge transdisciplinarity, then they may be able to train a different kind of critically thinking engineer, who reflects on and rewrite the co-construction of public welfare, the understanding and respect for the rules of natural cycles and the management of the technological systems that he or she knows [36]."

V. Conclusion

The CRAiEDL STEAM Collective's project showcases the value and effectiveness of using art and research-creation in a STEAM context to critically examine the rapidly evolving world of technology and AI. Through their interdisciplinary collaboration, the collective produced two critical artworks that shed light on important ethical issues in the tech industry.

We concluded from our pilot projects using the unique critical lens of the art to examine AI using STEAM and research-creation methodologies was a successful approach worth investing in for future research. Through this approach, the collective was able to gain valuable insights into the STEAM process, engineering education and the complex issues surrounding AI and its integration into society, while also fostering critical thinking skills.

These methodologies can contribute to the development of STEAM curricula and engineering pedagogy that encourage students to take a critical and creative approach in exploring ethical challenges in technology and society.

The use of art in this research methodology allowed the collective to explore the intersection of technology and society in new and creative ways, while also providing meaningful

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engagement for those outside the traditional STEM disciplines. Ultimately, the research methodology used by the CRAiEDL STEAM Collective demonstrates the power of STEAM methodology in shaping the future of technology and society and highlights the importance of engaging with a diverse range of perspectives and approaches in addressing complex societal challenges.

Recommendations

A STEAM approach and research-creation methodology can serve as a model for future research on emerging technologies and their ethical implications, as well as providing an interesting approach to engineering education. Bringing together diverse perspectives and expertise is crucial in creating responsible and innovative solutions to the ethical challenges posed by technology. Thus, our findings suggest STEAM holds great promise for engineering design beyond the educational setting.

This project has drawn the attention of national journalists, which confirms the relevance of such research and artworks for the general public. We recommend that future studies explore more ways to make transdisciplinary collaboration accessible and engaging for the public. This could be done by creating interactive installations or workshops that use art and technology to provoke discussion and reflection on the ethical implications of emerging technologies.

Moreover, we recommend that STEAM curricula and pedagogy incorporate research-creation methodologies and crossdisciplinary collaboration as an integral part of exploring the ethical dimensions of emerging technologies in engineering education. By doing so, students can learn to work effectively with those in other disciplines to co-develop critical and creative skills that are essential in addressing complex societal challenges. As the STEAM approach can accommodate the creation of a broad range research and design outputs beyond research-creation (e.g. to support policy or tech development), incorporating it in engineering educations primes graduates to address the complex sociotechnical challenges of the day, how to responsibly develop and deploy AI among them.

Finally, it is crucial to continue supporting and funding interdisciplinary research that examines the ethical implications of AI and other emerging technologies, especially considering the recent rapid evolution and general access to generative AI tools. A STEAM approach to research supports critical investigations. STEAM can help ensure that the benefits of new technologies are maximized while minimizing potential negative impacts on society.

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