

Programming Pedagogy in the Age of Accessible Artificial Intelligence

Lakshmi Preethi Kamak

Department of Computer Science
Lakehead University

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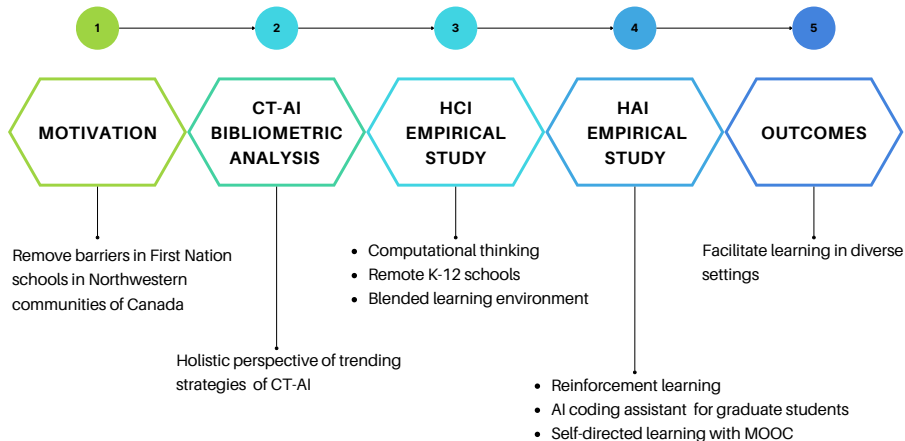


Figure: Overview of the studies presented in this thesis

With the increase of accessible artificial intelligence (AI), there is a need for an educational shift. The third wave of AI sees collaboration between Human-Computer Interaction (HCI) and AI engineers [1]. Human-AI Interaction research focuses on enhancing human capabilities rather than replacing them.

Objective:

- Enhancing programming pedagogy for novice programmers.
- Overcoming cognitive overload and poor user experience.
- Catering to different learning styles and needs.
- Leveraging computational thinking (CT) ¹ methods and accessible AI technologies with HCI and HAI principles.

¹“Computational thinking allows us to take a complex problem, understand what the problem is and develop possible solutions. We can then present these solutions in a way both can understand” [2].

In-depth investigation of the growing trend of CT and AI using academic literature through performance analysis and science mapping methods.

Research Questions:

- **RQ1:** How has the frequency distribution of CT-AI research publications changed over time?
- **RQ2:** Which nations, journals and authors are emerging in CT-AI research?
- **RQ3:** How have research development paths and research areas shifted over time in programming pedagogy?

VOSViewer- Network visualization tool to explore scientific relationships [3].

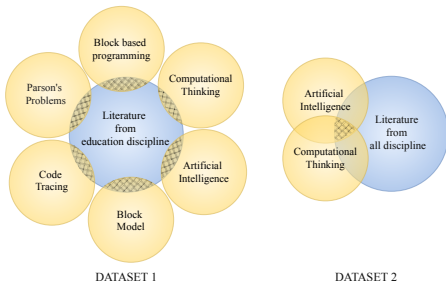


Figure: Architecture diagram of dataset 1 ($\mathbb{D}1$) and dataset 2 ($\mathbb{D}2$) representing extracts from the literature highlighted with cross hatching

- Multi-step investigation process with **Web of Science Core Collection** as the data source [4].
- $\mathbb{D}1$ for programming pedagogy literature (1982 - 2023), 1062 articles.
- $\mathbb{D}2$ for CT-AI literature (2010 - 2023), 157 articles.

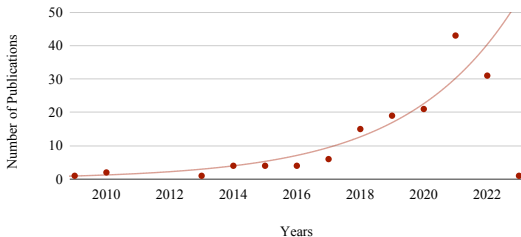


Figure: Annual distribution of CT-AI research publications

Frequency distribution of CT-AI research publications:

- Initial exploration phase (2009-2016) - 16 publications, averaging 2-3 per year.
- Rapid development phase (2017-2023) - 136 publications (89.47%), averaging 19 per year.

Interdisciplinary analysis: Main focus of the research is on the field of Education, as it accounts for almost half of all publications.

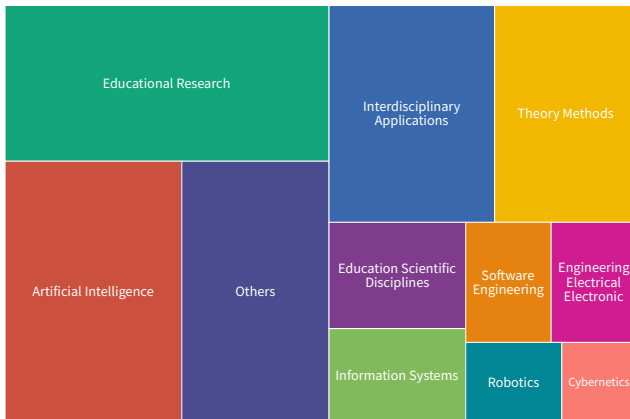


Figure: Top research areas from CT-AI literature

CT-AI Performance Analysis

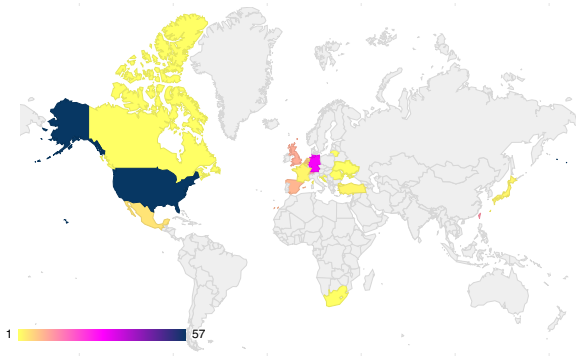


Figure: Countries contributing to CT-AI research

Country	Publications
United States	57
Germany	30
Switzerland	14
Taiwan	13
United Kingdom	10
Spain	9
Netherlands	6
Mexico	4
Belgium	3
Turkey	2
Japan	2
Hong Kong	2
France	2
Canada	1
Croatia	1
Ukraine	1
South Africa	1
Romania	1
Lithuania	1

- **Geo Analysis:** Resource distribution, research capacity, and international collaboration. Occurring mostly in developed countries with advanced technological infrastructure and research funding.

- **Emerging CT-AI publication sources:** Robotics and Autonomous Systems has the highest number of citations, 84 with one publication.

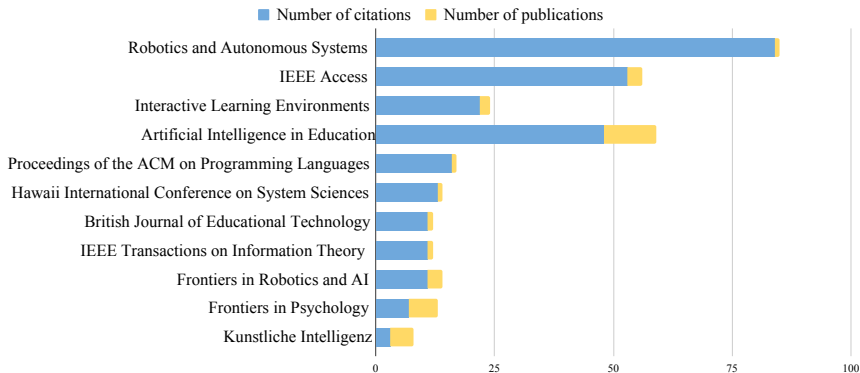


Figure: Journal and conference distribution of CT-AI research

- CT is the dominant pedagogy since its introduction, with node size of 532 occurrences and 1920 total link strength (TLS).
- The red cluster indicates the relationship with artificial intelligence.

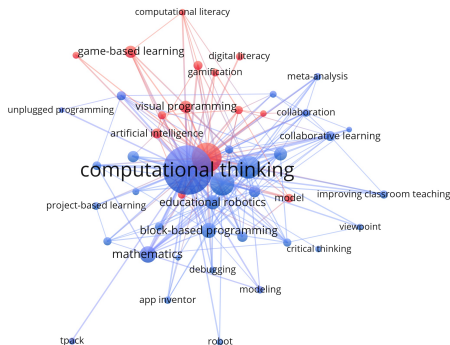


Figure: Co-word network map of the keywords in abstract and title from programming pedagogy literature

- Co-word network map of the keywords in abstract and title from CT-AI literature. The five distinct clusters identifies the themes.

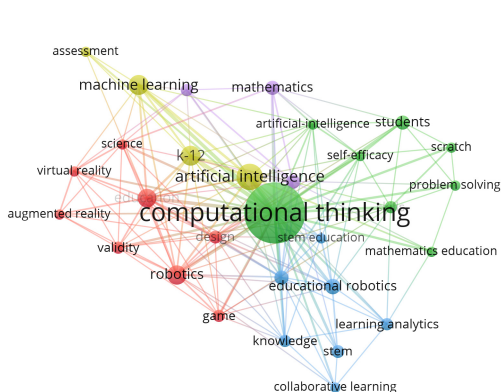


Figure: CT-AI co-word network map

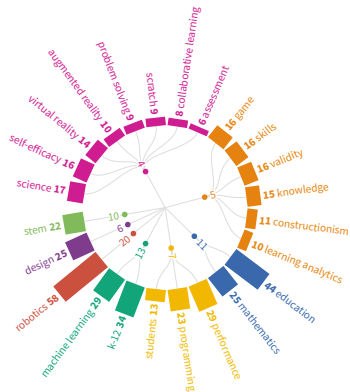


Figure: Keyword nodes size inside vs TLS outside

- The CT-AI themes indicating the research development paths and research areas.
- The keyword in the clusters traces back to the paper's title from D2.

Table: Cluster information from co-word knowledge map

Cluster	Theme	Keywords
1	CT-AI in education	Artificial-intelligence, computational thinking, mathematics education, problem solving, scratch, self-efficacy, skills, students
2	Augmented and virtual reality as educational resources	augmented reality, design, education, game, robotics, science, validity, virtual reality
3	Robotics based learning methodologies	collaborative learning, educational robotics, knowledge, learning analytics, performance, stem ² , stem education
4	AI and Machine Learning in K-12 ³	artificial intelligence, assessment, k-12, machine learning
5	Mathematics and Programming	constructionism ⁴ , mathematics, programming

²STEM represents Science, technology, engineering, and mathematics

³K-12 represents kindergarten through 12th grade

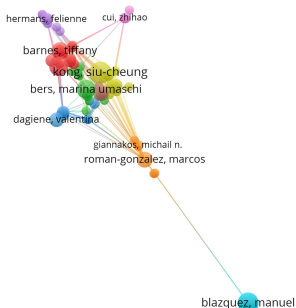
⁴"Constructionism is an educational theory holding that children learn most effectively when actively doing, or constructing, things, rather than being taught information in a traditional schooling method" [5]

- For example, “Robotics based learning methodologies” theme contains the RoboCupJunior study which leading the CT-AI research with the most citations, focusing on technological advancement through robotics competitions [6].

Table: Top research works leading CT-AI research with citations as on 21st February, 2023

Authors	Title	Citations in WoS	Citations in Google Scholar	Published Year
Eguchi, A	RoboCupJunior for promoting STEM education, 21st century skills, and technological advancement through robotics competition [6]	84	251	2016
Williams, R et al.	PopBots: Designing an Artificial Intelligence Curriculum for Early Childhood Education [7]	34	106	2019
Estevez, J et al.	Gentle Introduction to Artificial Intelligence for High-School Students Using Scratch [8]	24	75	2019
Prendes, E et al.	Advanced technologies to face the challenge of educational innovation [9]	20	10	2021
Toivonen, T et al.	Co-Designing Machine Learning Apps in K-12 With Primary School Children [10]	18	36	2020

- Significant programming pedagogy contributors from $\mathbb{D}1$ and their pursuit of AI using $\mathbb{D}2$.
- Marina Umaschi Bers: 10 works, highest citations at 540, no AI focus.
- Marcos Román-González: 8 works, 279 citations, significant CT contributor, strong citation network.



Authors	Documents	Citations
Bers, Marina Umaschi	10	540
Román-González, Marcos	8	279
Kafai, Yasmin B.	4	276
Hsu, Ting-Chia	4	219
Weintrop, David	6	206
Repenning, Alexander	6	194
Kong, Siu-Cheung	12	182
Koh, Kyu Han	4	180
Grover, Shuchi	4	174
Basu, Satabdi	5	168
Basawapatna, Ashok	5	161
Robles, Gregorio	10	134

Table: Influential programming pedagogy authors

- Overall, the study highlights CT-AI literature as a facet of programming pedagogy (2009 - 2023).
- Provides essential foundation for our following empirical studies.

Table: Top CT-AI research works by influential programming pedagogy authors

Authors	Title	Publication year
Kafai, Y et al.	Survey: Artificial Intelligence, Computational Thinking and Learning[11]	2022
Hsu, T et al.	The Effects on Secondary School Students of Applying Experiential Learning ⁵ to the Conversational AI Learning Curriculum[13]	2022
Román-González, M et al.	LearningML: A Tool to Foster Computational Thinking Skills Through Practical Artificial Intelligence Projects [14]	2020
Román-González, M, Robles, G et al.	Developing Computational Thinking at School with Machine Learning: An exploration [15]	2019

⁵“Experiential learning is an engaged learning process whereby students “learn by doing” and by reflecting on the experience” [12]

Evaluating the efficacy of Python Scaffolding to teach Computational Thinking in Remote Schools



PROGRAMMING PEDAGOGY

Computational thinking methods
Scaffolding techniques with Python
Blended Learning environment



HCI PRINCIPLES

Measure participant's perceptions and
user's subjective experience.
Metrics - *Ease of use, Success rate*



RESEARCH PARTICIPANTS

Grade 7,8 students - Armstrong Public
School
Remote Schools Outreach - Whitesand
and Gull Bay First Nations
communities



OUTCOMES

Curriculum and assessment tool
Aligned with Ontario learning outcomes
Identify STEM potential for remote
school programs

Figure: Overview of the study

- Adoption of coding in the Ontario mathematics curriculum for grades 1 to 8 in 2020 [16].
- **Objective:** Develop accelerated computer science education for remote middle schools in Northwestern(NW) Ontario given sparse resources.
- **Delivery method:** Blended learning ⁶, using D2L ⁷ as technology solution for remote school students.

Table: Coding expectations in the Ontario mathematics curriculum for grades 1 to 8 [18]

Grade	Coding Concepts
1	Sequential events
2	Concurrent events
3	Repeating events
4	Nested events
5	Conditional statements
6	Efficiency of code
7	Defined count and/or subprogram
8	Analysis of data

⁶ “Blended learning systems combine face-to-face instruction with computer-mediated instruction” [17].

⁷ Desire 2 Learn (D2L), an online learning management system.

- **RQ1:** What is the student's level of preparedness for a blended learning environment?
- **RQ2:** What is the effectiveness of the Python scaffolding ⁸ technique for teaching computational thinking?

⁸ "Scaffolding refers to a method where teachers offer a particular kind of support to students as they learn and develop a new concept or skill" [19]

- Which algorithm gets the corn to the beans and squash using the red path?
-
- A)

```
while(corn_collects_all == true):  
    if(block != 'chickens'):  
        move_forward(1)  
        turn_north()  
        move_forward(1)  
        turn_east()
```
- B)

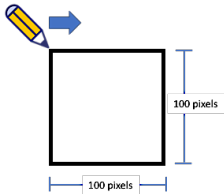
```
while(corn_collects_all == true):  
    if(block != 'chickens'):  
        move_forward(2)  
        turn_east()  
        move_forward(2)  
        turn_north()
```

9 "Scratch is a block-based visual programming tool to build computing skills"

- The pilot survey was conducted at the end of the course.
- The Research Ethics Board of Lakehead University has approved the research.
- Research Participants (12) include students who identify as First Nation, Metis and/or Inuit from Whitesand and Gull Bay First Nations communities were involved as an “incidental” representative group.
- The survey was adapted from two questionnaires:
 - 1 Callysto CT assessment tool Questionnaire (CTQ) [21]
 - 2 Blended Learning Questionnaire (BLQ) [22]

- Scratch code in the original CTQ was replaced with Python-based block code.
- Measured digital literacy, attitude towards CT, coding experience, data literacy, spatial CT skills, programming skills.

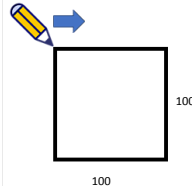
The instructions below should make the pencil draw the square **once**. The pencil starts at the upper-left corner position and moves in the direction of the arrow.



What is the error in the instructions?

- (a) The "repeat" loop should repeat 2 times.
- (b) The "move" block should be outside the loop.
- (c) The "turn right" block should be inside the loop, after the "move" block.
- (d) The "turn right" block should be inside the loop, before the "move" block.

The instructions below should make the pencil draw the square **once**. The pencil starts at the upper-left corner position and moves in the direction of the arrow.



```
for x in range(4):  
    move_forward(100)  
    turn_right()
```

What is the error in the instructions?

- (a) The "repeat" loop should repeat 2 times.
- (b) The "move" block should be outside the loop.
- (c) The "turn right" block should be inside the loop, after the "move" block.
- (d) The "turn right" block should be inside the loop, before the "move" block.

Figure: Comparison of the original Callysto CTt survey item sample and the translated CT survey item with visual blocks [21]

- Adapted the original BLQ designed for university education students to accommodate middle school student's readability levels and demographic.
- Measures feedback on the course delivery method, the student blended learning experience.
- **Original:** *"In comparison to the traditional classroom teaching, how would you describe the QUALITY OF FEEDBACK on coursework assessment that is received if the module is taught by blended learning?"* [22]
- **Translated:** *"How is the QUALITY OF FEEDBACK on your exercises in blended learning when compared to classroom teaching?"*

To test the suitability for grades 7 and 8 the below grade-level indicators assess and equate the readability of the survey text to the school grade-level system [23].

$$\text{FleschKincaidGradeLevel} = 0.39 \left(\frac{\text{words}}{\text{sentences}} \right) + 11.8 \left(\frac{\text{syllables}}{\text{words}} \right) \quad (1)$$

$$\text{GunningFogScore} = 0.4 \left[\frac{\text{words}}{\text{sentences}} + 100 \left(\frac{\text{complexWords}}{\text{words}} \right) \right] \quad (2)$$

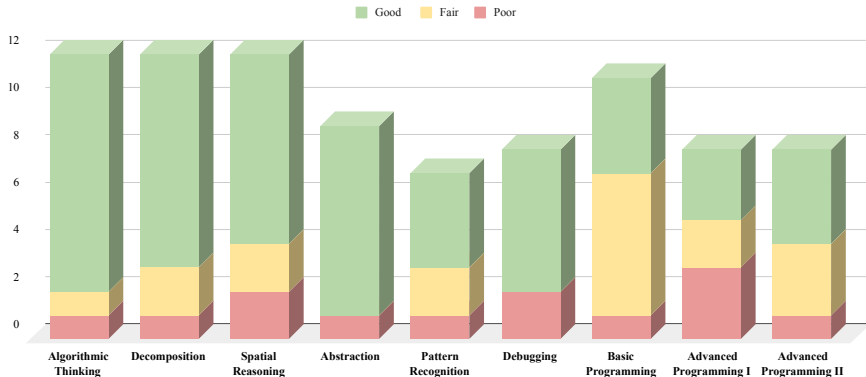
$$\text{ColemanLiauIndex} = 5.89 \left(\frac{\text{characters}}{\text{words}} \right) - 0.3 \left(\frac{\text{sentences}}{\text{words}} \right) \quad (3)$$

$$\text{AutomatedReadabilityIndex} = 4.71 \left(\frac{\text{characters}}{\text{words}} \right) + 0.5 \left(\frac{\text{words}}{\text{sentences}} \right) \quad (4)$$

Table: Readability test scores of the original BL survey and translated BL survey

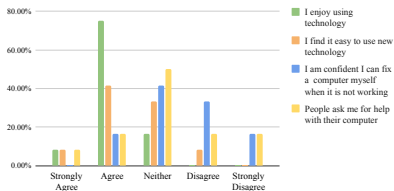
Readability Tests	Original Survey	Translated Survey
Flesch Kincaid Grade Level	9.163	6.976
Gunning Fog Score	10.053	8.554
Coleman Liau Index	10.512	8.600
Automated Readability Index	12.300	11.357
Average Score	10.507	8.872

- 83% of participants excelled in applying basic CT concepts.
- 4 out of 12 students showed exceptional computational talent, as indicated by their high scores (89.58%, 88.54%, 80.21%, 73.96%).

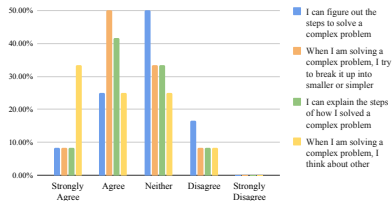


Digital literacy: Students clearly understand operating technology but require support in handling computer issues.

Experience in CT: The normal distribution of results is desirable for their first-time programming course as it indicates their range of abilities.



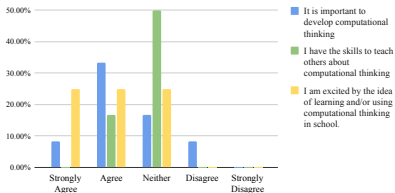
(a) Digital literacy



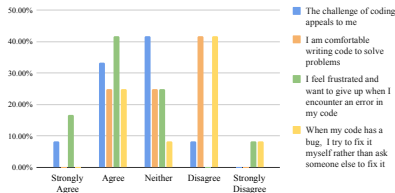
(b) Computational thinking skills

Figure: Student's self perception on CT aspects

- **Interest in CT:** Students feel unprepared to teach CT to their peers, possibly due to less interaction. We recommend peer teaching or collaborative learning resources for future training approaches.
- **Programming experience:** Despite less confidence in programming, students view coding as a positive challenge.



(a) Computational thinking interest



(b) Programming experience

Figure: Student's self perception on CT aspects

- Flexibility is the most significant advantage for the student to complete their assignments anytime and anywhere.
- Difficulty in travel during COVID-19 and adverse weather in NW Ontario.
- Some students with home responsibilities or disabilities find it challenging to attend in-person classes.

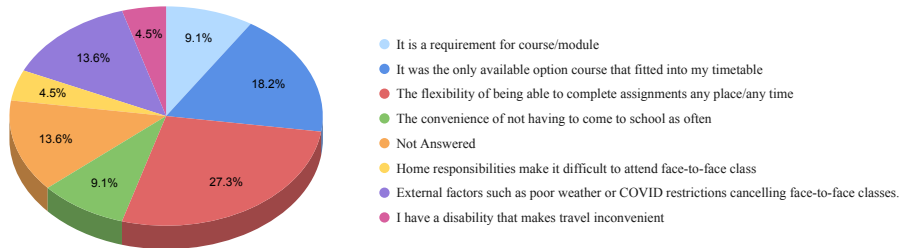
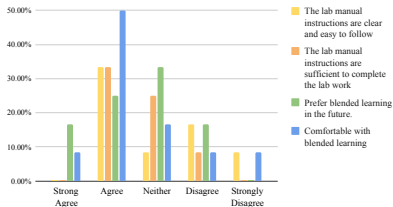
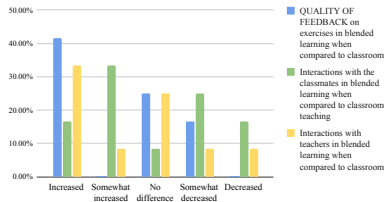


Figure: Student's subjective advantages in blended learning

- **BL experience:** Most students had a positive experience with the BL environment and while using the lab manuals.
- **BL vs Face-to-Face Learning:** Most students believe that the interaction with teachers and classmates and the quality of feedback on exercises have increased in BL.



(a) Blended learning course experience



(b) Comparison of student's experience in BL and in-person

Figure: Student's perception on BL aspects

- Moderate correlation (r-value 0.64) between CT and programming experience supports our supposition that Python enhances CT skills.

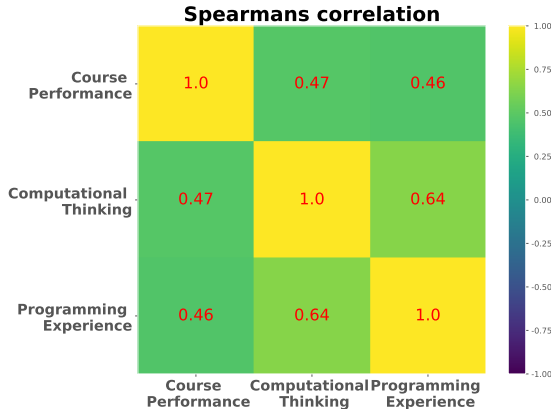


Figure: Spearman's correlation analysis of computational thinking related elements

- Custom-designed curriculum and assessment tool contributed to limited CT teaching resources.
- Survey data can be used as a benchmark for efficacy and progress measurement.
- Scaffolding intervention with Python is successful.
- Students are now more familiar with coding syntax and debugging and willing to learn in a BL environment.
- Peer teaching or collaborative learning resources are essential for future training approaches.
- Computationally talented students in NW Ontario with potential for advanced STEM programs.

Assessing the Impact of AI-Assisted Coding in Self-Directed Reinforcement Learning MOOC



PROGRAMMING PEDAGOGY

Self - Directed Learning with MOOC
AI Coding Assistant
Reinforcement learning



HAI PRINCIPLES

Examine participant's interaction using
hybrid HCI - HAI framework
Metrics - *Perceived usefulness, Ease of use,
Trust, Transparency, Explanation quality*



RESEARCH PARTICIPANTS

Graduate students - Lakehead University
Experiment Group - ChatGPT
Control Group - Manual coding with
Google



OUTCOMES

Academic potential of accessible AI
Technology acceptance of ChatGPT
Verification of potential information bias

Figure: Overview of the study

- RQ1: How do students perceive AI-assisted learning experience in terms of compatibility and trust?
- RQ2: Can using AI-assisted learning in MOOCs¹⁰ lead to information bias for students?
- RQ3: What is the extent of technology acceptance of ChatGPT¹¹ as a coding assistance tool among beginner and advanced programmers?

¹⁰ "A massive open online course (MOOC) is a model for delivering learning content online to any person who wants to take a course, with no limit on attendance." [24]

¹¹ ChatGPT is OpenAI's artificial intelligence chatbot

- To better understand the academic potential of accessible artificial intelligence.
- GPT-4, multimodal model outperformed humans on various professional and academic benchmarks [25].
- The studies have yet to explore complex subjects such as reinforcement learning.
- Likewise, incorporating AI-assisted tools for MOOCs also requires a comprehensive analysis of student perceptions.

Table: GPT coding exam scores for real-time exam simulations [26]

Exam	GPT-4 (no vision)	GPT-3.5
Leetcode (easy)	31 / 41	12 / 41
Leetcode (medium)	21 / 80	8 / 80
Leetcode (hard)	3 / 45	0 / 45

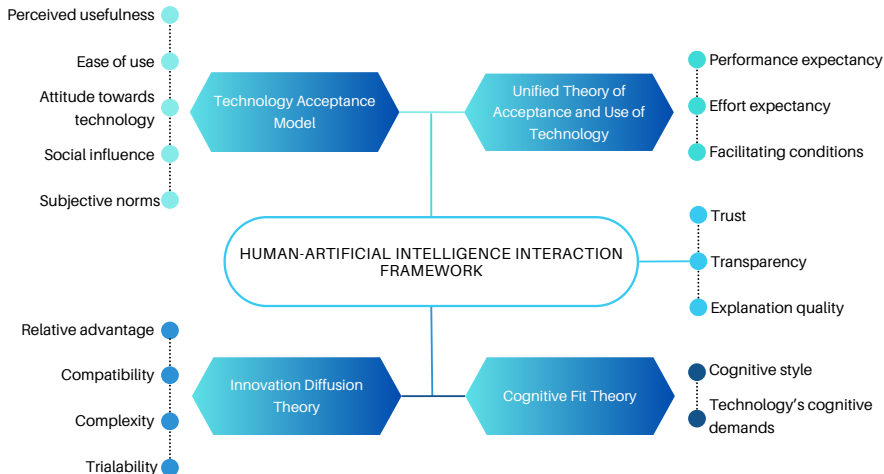


Figure: Human-Artificial Intelligence Interaction Evaluation Framework

- Kaggle course “Intro to Game AI and Reinforcement Learning^a” [28].
- Designed tasks for the below key evaluation areas:
 - 1 Implementing a RL agent for tic-tac-toe game
 - 2 Setting reward function
 - 3 Minimax Algorithm
 - 4 Bug Fixing in Q-values
 - 5 Alpha-Beta pruning algorithm

^a“Reinforcement learning (RL) is the problem faced by an agent that must learn behavior through trial-and-error interactions with a dynamic environment [27].

B. Game theory and Reinforcement Learning knowledge test

- 1) Implement a smart Tic Tac Toe Agent that uses reinforcement learning with an N-step look ahead approach with your chosen programming language and algorithm [34].
- 2) Consider a Tic Tac Toe game with the below game tree where X is the maximizing player, and O is the minimizing player. Based on the minimax principle, what move should X make? [45]

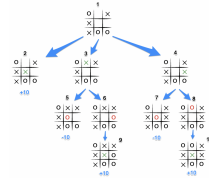


Fig. 10. Game tree for the Minimax algorithm test from - [45]

- State 2
- State 3
- State 4
- All remaining moves result in a tie

Figure: Sample RL task from developed survey

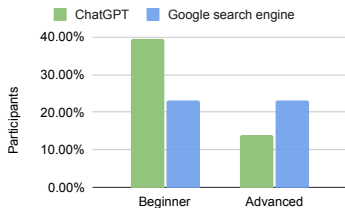
- **Control group**- manually coded by referring Google.
- **Experiment group**- access to ChatGPT (GPT 3.5, GPT-4).

Table: Summary of Participant Demographics

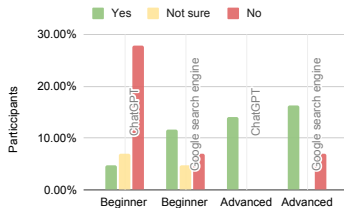
Experience in Reinforcement Learning	Number of Participants
Beginner	27
Advanced - Prior Experience	16
Advanced - Formal training	6

- Based on Tri-Council Policy Statement (TCPS 2), Ethical Conduct for Research Involving Humans, Article 2.5 this study is exempt from ethical review.
- **Ethics category**: Educational research conducted for professional development only.

Beginner programmers (39.53%) used ChatGPT more often. ChatGPT is ideal for beginners, while Advanced programmers prefer to rely on their own knowledge and specialized tools.



(a) Preferences of students based on their coding experience



(b) Attitude towards potential bias

Figure: General attitude towards coding assistance tools

Most participants who did not encounter incorrect information were beginners (27.91%), whereas advanced programmers reported otherwise as they evaluate outcomes critically with prior expertise.

Participant 25 prompt: Question 2: Given below the reward function for a tic tac toe smart agent with p1 as player 1 and p2 as player 2. Would it be possible to change the tie reward to benefit p2 more? Provide values for variables A and B.

```
def giveReward(self):  
    result = self.winner()  
    # backpropagate reward  
    if result == 1:  
        self.p1.feedReward(1)  
        self.p2.feedReward(0)  
    elif result == -1:  
        self.p1.feedReward(0)  
        self.p2.feedReward(1)  
    else:  
        self.p1.feedReward(A)  
        self.p2.feedReward(B)
```

The possible answers are:

A= (0.1), B= (0.5)

A= (0.5), B= (0.1)

A= (0), B= (0)

GPT-4 response: Yes, you can change the tie reward to benefit player 2 more by assigning a higher reward value to player 2 (p2) compared to player 1 (p1) in case of a tie. Based on the given answer choices, you can set A = 0.1 and B = 0.5, which will give a higher reward to player 2 in case of a tie. The modified reward function would look like this:
python
Copy code

Readability tests	Grade level
Flesch Kincaid Grade Level	8.54
Gunning Fog Score	9.92
Smog Index	10.22
Automated Readability Index	10.04
Coleman Liau Index	7.55
Average Score	9.254

Table: Reading ease of the ChatGPT prompts on RL explanation

Average readability of 9.254 indicates that the prompts are easy to comprehend the complex subject.

Figure: Sample transcript of Participant interaction with ChatGPT

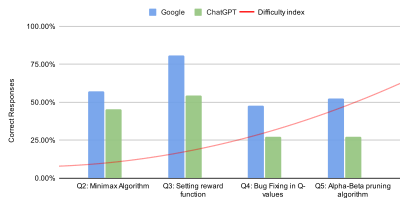
RL Implementation task:

- Google users tended to rely on the algorithms readily available in tutorials and blogs.
- ChatGPT users had access to more complex algorithms.

Table: The variety of Reinforcement Learning approaches implemented by participants for Question 1

AI context Participants
N-Step SARSA algorithm
Q-learning algorithm with a Q-value table with greedy policy
Q-learning algorithm with Q-value estimator with epsilon-greedy policy
Q-learning algorithm with N-step look ahead using neural networks
Non-AI context Participants
Minimax algorithm
One step look ahead algorithm
Q-learning algorithm with the epsilon-greedy policy
Pseudocodes of the Q-learning algorithm
Pseudocodes of Minimax algorithm

RL test performance: The success rate of the AI context group is comparatively lower for all the tasks and with increasing task difficulty.

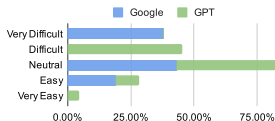


(a) Reinforcement learning coding test performance

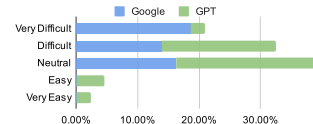
Coding assistant tool	RL Coding tasks	Correct responses	Difficulty index
Google	Setting reward function	80.95%	2
ChatGPT	Setting reward function	54.55%	2
Google	Minimax algorithm	57.14%	1
ChatGPT	Minimax algorithm	45.45%	1
Google	Bug fixing in Q-values	47.62%	3
ChatGPT	Bug fixing in Q-values	27.27%	3
Google	Alpha-Beta pruning	52.38%	5
ChatGPT	Alpha-Beta pruning	27.27%	5

(b) Explicit numerical information on the difficulty index

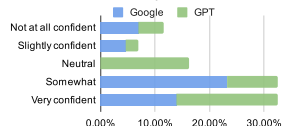
Effort for MOOC



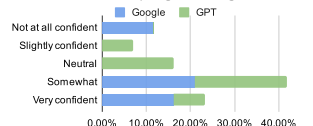
Effort for RL test



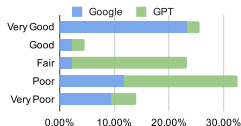
Confidence in RL explanation



Confidence in RL programming



RL test performance



Confidence in the assistance tool

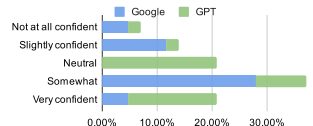


Figure: Distribution of the test performance, perceived difficulty and confidence of AI and non-AI context groups

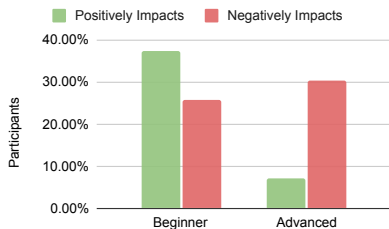
- **Effort expectancy:** ChatGPT is easier to use than Google for RL tasks.
- Many users have much higher confidence in ChatGPT and their ability to explain RL, but they mostly perform poorly in the RL test.

Table: Statistical Significance of Welch t-test's for the test performance, perceived difficulty and confidence of AI and non-AI context groups

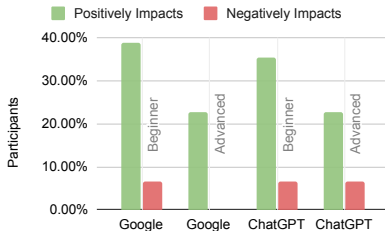
	Results	p-value
Test performance	Google > ChatGPT	2.7586e - 6
Effort for RL test	Google > ChatGPT	0.048
Confidence in RL explanation	ChatGPT > Google (Slightly higher)	0.032
Confidence in Coding assistance tool	ChatGPT > Google	0.014

This implies that using AI-assisted learning in MOOCs may lead to potential information bias among self-directed learners as they may rely too heavily on the incomplete recommendations and feedback the AI system provide.

Perceived Usefulness: Pre-test, Majority of the beginners (37.2%) felt that ChatGPT positively impacts critical thinking, while advanced programmers felt that otherwise.



(a) Critical thinking on using ChatGPT pre-test



(b) Self-direction post-test

Figure: Perceived impact on (a) critical thinking on using ChatGPT pre-test and on their (b) self-direction post-test

Post-test, a significant difference in attitude; 81.8% of the ChatGPT participants felt it was a positive impact.

Perceived Usefulness: Student's top priorities are saving time, increasing efficiency, and improving accuracy in processing data. Students prefer to code manually to custom-fit their data to the problem, rather than using coding assistance tools for data processing activities.

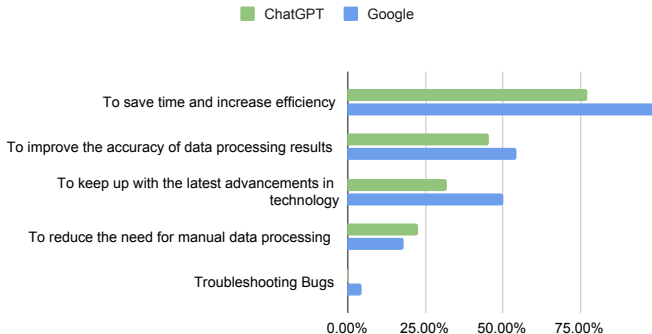


Figure: Perceived usefulness of the coding assistance tools

- 1 **Performance expectancy**: Most ChatGPT users (58.82%) felt adopting the AI-assistance tool improved their learning experience.
- 2 **Complexity**: Majority of the Google users (79.41%) felt that AI assistance could have made their self-learning journey easier.
- 3 **Transparency**: ChatGPT needs to cite its source more accurately.
- 4 **Trialability**: GPT 3.5 is a free research preview tool that allows users to test before adopting paid services of GPT - 4 model.
- 5 **Creativity**: Creativity is not compromised as AI context participants incorporate a variety of approaches to implement RL tasks.
- 6 **Reliability**: Code responses sometimes need to be completed with user intervention.
- 7 **Ease of Use**: Provides boilerplate code useful for cold start challenges, saving time and effort.

- 1 ChatGPT as a coding assistance tool among beginner and advanced programmers is widely accepted with high **perceived usefulness, compatibility, ease of use** and few concerns about **trust** and **reliability**.
- 2 **Facilitating conditions** can aid students to access the necessary resources and support to address any biases they perceive.

The research conducted throughout my MSc focused on leveraging technology and design to improve programming education for students with diverse learning needs.

- Demonstrated the efficacy of Python scaffolding in teaching Computational thinking in remote schools in NorthWestern Ontario using visual aids and the computational talent for STEM potential.
- Established the OpenAI's ChatGPT acceptance as a coding assistance tool with HAI metrics, while emphasizing the need to facilitate access to resources to verify wrong information.

In the course of completing my degree, I was fortunate to receive both financial and moral support from the following sources:

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- Resources provided by the Nijjii Indigenous Mentorship program

I also extend my gratitude to all of my colleagues at DaTALab, Lakehead University.

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A collection of three articles produced over the course of my MSc:

- The Convergence of Computational Thinking and Artificial Intelligence in Programming Pedagogy: A Bibliometric Analysis
(*Under review*)
- Assessing the impact of using Python to teach Computational Thinking for remote schools in a Blended Learning environment
(*Accepted in conference*)
- Assessing the Impact of AI-Assisted Learning on Self-Directed Massive Open Online Courses. (*Submitted*)

Thank you!