Development of Exploring Computer Science With Lynx for Student Learning Geometry and Logo Programming Code

Thomas Walsh Jr., Ames Community Schools, United States

The IAFOR International Conference on Education in Hawaii 2022
Official Conference Proceedings

Abstract
Research on Logo programming contributing to student learning has appeared in the literature during the last four decades. Empirical and meta-analysis research studies support of teaching Logo coding in developing student cognitive problem-solving skills has been documented using teacher-mediated or guided instruction. Using guided instruction with teacher-mediated scaffolding *Exploring Computer Science with MicroworldsEX* (Walsh 2013-2017) has been found as an effective curriculum in preparing the author's elementary and middle school students using the Logo code language to create geometric graphic, animation, and gaming projects. The instructional curriculum updated to a cloud-based platform *Exploring Computer Science with Lynx* (Walsh 2020) is anticipated to provide continue support to students and teachers in learning Logo coding. The paper will discuss the author's journey in teaching Logo coding to students at the elementary and middle school level over a 30-year period. The classroom field experience along with research on Logo programming contributing to development of an e-book curriculum will be discussed. More research will be needed to study teacher scaffolding and mediation skills to support learning Logo using the Lynx platform along with transfer to other domains including programming environments like Python or JavaScript. Future employment of computer-programming jobs will be best for applicants with experience in a variety of programming languages and newest programming tools (Bureau of Labor Statistics, 2021).

Keywords: Logo Coding, E-book Teaching Curriculum, Scaffolding Instruction, Discovery Learning Projects with Mediation Support, Lynx Platform, Geometry, Programming Skills

Introduction

The paper will begin defining Logo with the development of the language and how the philosophy of Piaget's constructivism supports student project based learning of programming. The author will then discuss field experience in teaching Logo coding at the elementary and middle school level with examples of student projects. Research supporting guided instruction in student learning Logo coding will be presented. Information based on classroom field experience, findings of a Logo teacher staff development, and research reporting will be presented contributing to development of a guided Logo e-book curriculum. Future direction in teaching Logo coding related to transfer to other domains and programming environments along with use of the Lynx platform will be discussed.

Logo and Development

Seymour Papert and his colleagues at the Massachusetts Institute of Technology (MIT) Artificial Intelligence Laboratory developed logo, which means "word" in Greek, in the late 1960's. Logo was designed to provide an environment in which students can learn as naturally as possible. Papert (1980) envisioned the computer as a means of making learning an active and exciting process and claimed that Logo enabled children to program the computer rather than the computer to program the child. Papert believed that Logo was a tool providing a "Mathland" in which the computer becomes an instrument for students to learn mathematics as naturally as they learn to speak. Papert (1980b) stated that Logo has no threshold and no ceiling. This means that Logo, primarily designed for children, can provide early programming instructional use with preschool handicapped students, and can provide secondary student application in mathematical problem solving, geometric theory, science education, language activities, computer programming, and other content areas. Papert believed that children of all ages and from all social backgrounds can do much more than they are believed capable of doing when given the tools and the opportunity (Papert 1999).

The Logo philosophy of education is described as Constructivism, a theory of learning supported by Jean Piaget. Papert extended the Constructivism of Piaget to include the idea that a good way to support the building of knowledge in one's head is to build something in the real world – a computer program, robot, drawing, or a musical composition. Constructivism is both a theory of learning and strategy of education referred to as child-centered, learner-centered, progressive, active, hands-on, and project-based practices (Logo Foundation 2015). In this Logo environment the role of the teacher is collaborator and facilitator in providing scaffolding support for the students' learning.

Grade 3 Teaching of Logo and LogoWriter in the Schools

Interest in teaching Logo developed in the field as a third grade classroom teacher in the Ames Community School District (ACSD). Students practiced using the early Logo version on Apple computers, with the 'turtle' appearing as a green triangle. Students used turtle primitives, Logo's built-in vocabulary, to draw basic geometric shapes on the amber or green screen monitors, and then saved their projects to 5 ¼" floppy disks or printed them on an inkjet printer. Greater interest and teaching of program coding developed when LogoWriter became available in 1987. At this time the ACSD provided a weeklong staff development in an upgraded Logo version called LogoWriter. With this training Logo instruction increased, supported with the addition of Macintosh computer labs, providing students opportunity to develop graphics incorporating geometric shapes. Grade three students began to build and combine program procedures to create modular programs. The use of two or more programs (subprocedures) combined into a superprocedure was easy for students to understand once they were given a brief introduction and a demonstration that modeled the process. The students developed coding projects were published in the school writing center for sharing. Examples of the types of projects created are shown in Figure 1. Given this version of LogoWriter, integrated with a Word processing and shape figures, students also developed Logo graphics to accompany adventure stories and created rebus stories (i.e., a rebus story places small images or pictures-turtle stamped shapes substituted for some of the words.)

LogoWriter Modular Programs

- To RowBoat with To Boat and To Row – Rowboat graphic
- To Hat with To Sleep and To Tinsel – Sleeping hat
- To Tarne with To Star, To Circle and To Song – Circle star with tune
- To Wheel with To Circle and To Big – Wheel polyspiral
- To Super with To Sun and To Colors – Sun polyspiral
- To AO with To Awesome and To Orbit – Space object
- To Super with To Move and To Spiderweb – Spider in web
- To Super with To Sharkfin and To Water – Shark fin in water
- To Design with To Star, To Balloon, and To Square – Enclosed star graphic
- To Super with To Squad with To Arrest – Helicopter below sun spiral

Walsh (2013-2017)

Figure 1. Grade 3 LogoWriter Superprocedures with Subprocedures for Turtle Graphics

When Lego building blocks integrated with Logo coding became available, third grade students would work together in cooperative groups to create programs to run the machines they built (e.g., washer, car, or conveyer belt). Once students knew the basics of the programming language, they were able to transfer their knowledge of how to write programs for the turtle to writing programs for the Lego machines.

Research Support for Guided Instruction in Student Learning Logo Coding

Based on field experience with third graders, showing engagement and enthusiasm in learning coding, fostered interest in developing a Logo curriculum based on a hierarchical sequential presentation of Logo concepts (i.e., developmental progression of commands leading toward building program procedures). It was found providing some structure in the teaching of Logo concepts using student handouts, posters, and flashcards supported students learning of Logo primitive commands for developing Logo programs and turtle graphics.

Support for a more structured methodology in the teaching of Logo was substantiated in an inservice model implemented as a dissertation study at Iowa State University. The study is summarized as follows:

> The primary goal of the study was to develop a teacher-training model to improve and increase teacher use of Logo in the classroom. The in-service model was delivered to a sample of teachers in the ACSD and the research study found, based on profile interpretations on the Stages of Concern Questionnaire (Hall, George & Rutherford, 1986) and other data, all participants (except one n=18/19) made substantial shifts in concerns to higher stages. This suggests all participants (except one) had earlier concerns resolved and were ready to use Logo with students (Walsh 1992-1993).

In addition, the results from the study indicated that teachers were planning to instruct nonprogramming and programming aspects of Logo through discovery learning and problem-solving. Using a structured inservice training approach to learning Logo concepts and program procedures with training components (e.g., activity pages for classroom use, coding examples, teacher collaboration with cooperative learning, and time to develop projects) were found effective in developing Logo cognitive skills and promoting positive teacher attitudes toward using Logo with students.

Further support for developing a structured teaching approach for Logo instruction using discovery project-based learning was provided by a graduate colleague study at ISU conducting a Logo research project. Lee (1990) studied a cognitive monitoring strategy used for developing a guided programming project. The strategy involves having participants drawing the desired Logo graphic outcome by hand, decomposing the steps to write a program, writing a plan, writing codes or subprocedures, testing and identifying errors, and debugging the program. With Lee's permission to use cognitive monitoring in the classroom students were found to effectively problem solve using the strategy in developing Logo graphics and debugging program code errors.

Further support in teaching Logo using guided instruction and teacher scaffolding, along with benefits derived from this method of teaching, was found when conducting a literature review. It was found that research on Logo's contribution to student learning has appeared in the literature during the last four decades. Research on potential benefits, using teacher-mediated or guided instruction, is summarized as follows:

- Contributing to understanding of geometric concepts
- Facilitating students' understanding of geometric conceptualizations and thinking (e.g., understanding of angle sizes and geometric shapes)
- Increasing understanding of geometric transformation (symmetry, slides, and rotations)
- Supporting the development of cognitive and metacognitive skills (e.g., planning skills) including measures of creativity
- Improving problem-solving in decomposition skills, error recognition, and feedback
- Gains in divergent thinking, field dependence/independence (relationship of figures), and impulsivity/reflectivity
- More time on-task in problem solving, correcting of program errors, and benefits in self-esteem social skills during cooperative learning (Walsh 1994).

Some studies have suggested that Logo experiences using teacher-mediated instructional practices produce positive near transfer (e.g., debugging Logo programs transfers to map reading directions) and far transfer (to higher order thinking in another content subject area). These benefits along with others have been substantiated supporting learning Logo coding for developing critical thinking, task persistence or determination, problem-solving, processing skills, trial and error, geometric spatial visualization (Heggart 2014, Pardamean & Suparyanto 2015, Williams 2021, Porter 2021 and Khormi et.al. 2021) along with improved social skills and self-confidence (An 2017 and Morris 2021).

Of notable interest regarding the teaching of Logo was provided by Littlefield et. al. (1989). These authors reported the method of teaching Logo and its effects on the development and transfer of general thinking skills from the Logo environment to non-Logo problems needs consideration. The study of student learning providing structured and unstructured learning environments found support for goal-oriented structure in the training program using mediated teacher intervention. Littlefield et. al. (1989) report the features of mediation that apply directly to Logo instruction include framing, which involves the act of relating specific sets of behaviors to a broader framework of problem-solving (e.g., breaking down Logo subprocedures into manageable components). Another feature is bridging, which involves the act of relating processes that occur within one context to similar processes occurring elsewhere (e.g., using mediation to relate right and left turn degrees to time on a clock).

Further support for teacher mediation and scaffolding was provided in two meta-analyses conducted by Alfieri et. al. (2011) using a sample of 164 studies examining the effects of discovery learning practices. Most of these studies involved teaching domains in math, science, problem-solving, and computer skills. The results of the first meta-analysis indicate that unassisted discovery does not benefit learning. The analysis also found direct teaching is better than unassisted discovery; provide learners with worked examples, and use of timely feedback. The implications here suggest students benefit when provided with examples of Logo programs and procedures as learning models. The study also reports that students may benefit from individualized feedback on homework assignments with worked examples provided. The second meta-analyses suggest that teaching practices should employ scaffolding tasks that require learners to explain their own ideas. These authors report that feedback; worked examples, scaffolding, and elicited explanations are needed for learners to be redirected, to some extent, when they are misconstruing. Research supporting these student benefits are based on providing more structured presentation of coding procedures with programming model examples accompanied by teacher feedback, mediation and scaffolding of student learning (Littlefield et. al. 1989 & Alfriei et. al. 2011). Alfieri et. al. elaborate on this idea stating:

> *Feedback, scaffolding, and elicited explanations do so in more obvious ways through an interaction with the instructor, but worked examples help lead learners through problem sets in their entireties and perhaps help to promote accurate constructions as a result* (Alfriei et. al. 2011, 12).

The findings suggest that unassisted discovery does not benefit learners, whereas feedback, worked examples, scaffolding, and elicited explanations do.

Given initial fieldwork in coding with students, dissertation research with literature review, and support for more structured learning environment (e.g., cognitive monitoring) direction was provided for developing a Logo curriculum for student use to support teacher instruction. Activities for the curriculum were developed based on experience in the field working with students on Logo coding projects. A sequential lesson planned curriculum was needed balancing a structured discovery-learning environment for Logo project development supported by teacher scaffolding.

MicroworldsEX in the Schools and e-Book Development

During teaching tenure in the ACSD MicroWorldsEX became available for third grade students to create coding projects using this upgrades platform developed from Logo Computer Systems (LCSI). Teaching effectively required using teacher-mediated instruction to support student development of Logo programs in a discovery-learning environment for project development. With MicroWorldsEX and greater access to computers students had more time to develop Logo graphic programming projects. Some modular title programs with subprocedures and graphic names, developed by students are listed in Figure 2.

MicroWorlds Turtle Modular Super Programs

- To Super with To Trisqu and To Octahex – Overlapping octagon, hexagon, square, and triangle
- To Superpentaflower with To Superstar, To Pentagon, and To Flower – Flower graphic
- To Goku with To Meany, To Fatty, and To Calvin – Polyspiral circular design
- To Nesttunel with To Nest and To Tunel – Bird nest in a tunnel
- To Thingy with To Circle, To Karlie, To Wingy, and To Buggy – Cross-eyed face with red mouth

Walsh (2013-2017)

Figure 2. Grade 3 MicroWorldsEX Superprocedures with Subprocedures for Turtle Graphics

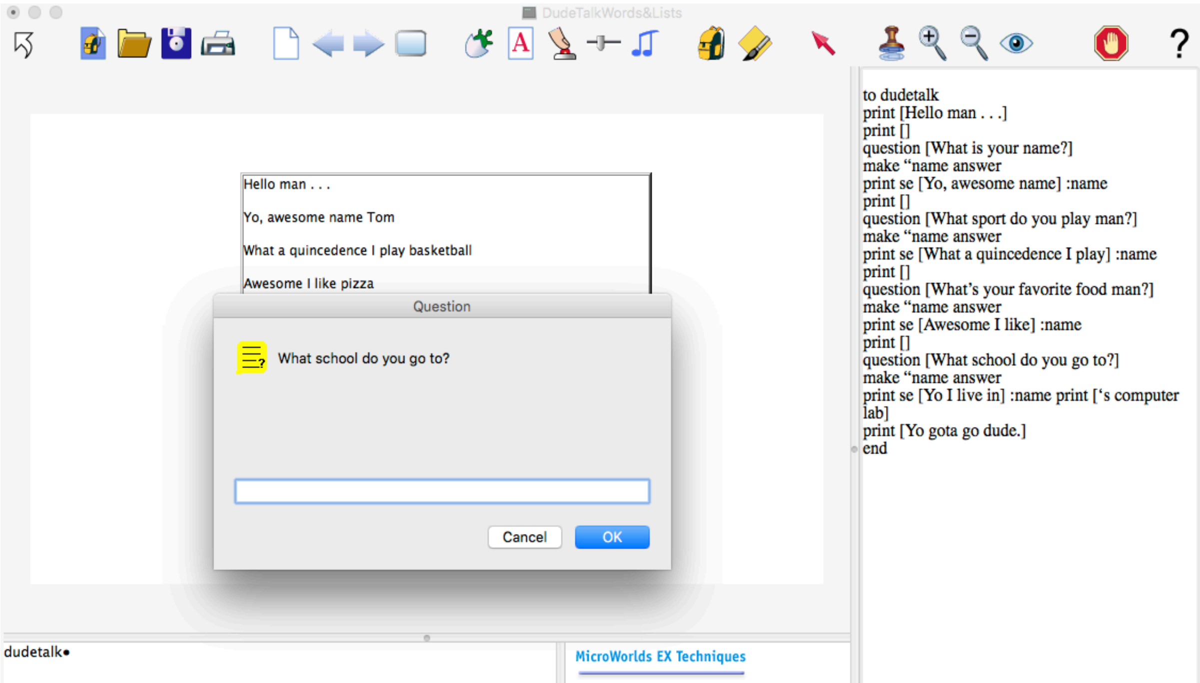
Using teacher scaffolding, students created modular programs such as the example created by a student displaying stacked slices of lime:

```
to limes
repeat 7[flower fd 60 rt 180]
end

to flower
setpensize 12
setc 67
repeat 60[triangle2]
setc 63
setpensize 3
repeat 30[triangle2]
end

to triangle2
repeat 3 [fd 30 rt 120]
rt 30
end
```

It was found with MicroWorldsEX students used program primitives to create simple recursion procedures and wrote codes using variables. For example, students enjoyed using recursion programming in which the name of the procedure itself (e.g., **triangle**) is used as the final instruction in the same procedure (just before the **end** line), so that the whole program runs repeatedly. Using recursion students would develop projects with overlapping shapes to create designs or polyspirals, sometimes making a flower pattern. Many students were able to add one or more variables to their program procedures. Below is a student example of a recursive variable program typed to create a turtle spider web:

```
to triangle :size
if :size > 150 [stop]
repeat 3 [fd :size rt 120]
rt 30
triangle :size + 3
end
```

Working with students in the Logo environment it became evident that levels and sophistication of coding projects varied given the diversity of the classroom. Some exceptional students were able to work ahead and develop animation program procedures. Another students was able to use the words and lists feature of MicrowordsEX to create interactive conversations (Figure 3).



Walsh (2013-2017)

Figure 3. MicroWorldsEX Version of a Student Interactive Words and Lists Project

It was found in the classroom that the Logo teaching environment provided inherent differentiation for instruction evident in the varied application of program procedures and use of the Logo language. The difference in sophistication of coding projects was evident, particularly when students were integrated from resource room or mainstreaming programs. Sharing of graphic project designs in class were presented on-screen or printed for publication at the school writing center.

Continued tenure in the ACSD provided opportunity teaching Logo coding to grade six gifted students at the middle school as part of math instruction in the Extended Learning Program (ELP). Using MicroworldsEX lesson plans were further developed and extended to cover more advanced programming procedures and project work in creating turtle geometric graphics, animation, and interactive conversations. In addition to meeting with ELP math groups, coding with MicroWorldsEX was provided to all grade six classrooms covering the following activities:

- Practice with turtle primitive commands for graphics
- Use the repeat procedure to explore and create geometric shapes
- Create graphics by using the button tool
- Teach the turtle a new word by writing a procedure
- Apply program tool procedures (e.g., text boxes).

Instruction at this time with students receiving services in ELP and in the classroom included visual demonstration of primitive commands, program procedures, and use MicroworldsEX tool features (e.g. button, text box, or linking pages) added to a Logo project. Students were provided with support materials including flashcard practice of Logo primitives, activity handouts listing turtle code commands for practicing, brief explanations about entering different program procedures (e.g., recursion, variable, interactive, and animation), and use of posters showing program procedure examples. It was found to be helpful in providing students handouts and practice using degrees to support their geometric turtle graphic projects.

The cognitive monitoring strategy was used most effectively with grade six students in developing a student guided programming project. The strategy (Lee, 1990) was written as a handout with lines and boxes for the planned graphic, decomposition (main shapes), written plan, program executed code, outcome graphic and debugging steps. For example, a student wants to draw a house. The decomposed shapes identified are a triangle on top of a square, and this is hand-drawn as the planned graphic. The student writes the plan as a program with a roof (the triangle) and a square. The executed program may be written as follows:

```
to house
repeat 3 [fd 100 rt 90]
fd 100 rt 90 fd 100 rt 90
rt 45 lt 45
end
```

The executed graphic created with this program turns out not to be a house, which means the student must debug the program and keep trying the new versions until the desired drawn graphic outcome is achieved. The cognitive monitoring strategy involves student planning skills, metacognitive thinking, and problem solving. It was found students need support when initiating the planned activity in developing a project idea that is not too difficult or easy to solve. Some graphic ideas developed by students were too difficult for planning and debugging. It was found that showing students how to debug procedures is a helpful strategy for finding and fixing code errors. This also alleviates time required by the teachers in finding student errors, especially for large classroom sessions.

Development of Curriculum Programs

Incorporating graduate research conducted at Iowa State University along with learning activities provided for elementary and ELP students contributed to development of a curriculum program for teaching Logo coding to students. *Exploring Computer Science with MicroworldsEX* (Walsh, 2013-2017) LCSI published e-book was written as a structured learning methodology of learning activity lessons, with opportunities for discovery and exploration, to support student learning in a "Microworlds" project-based environment to create geometric graphics, animation, and gaming using the Logo programming language.

Guided instruction was found for the potential cognitive benefits for teaching Logo to be achieved by implementing more carefully planned teacher-directed lessons balanced with student problem solving and discovery learning using teacher-mediated scaffolding. Working with students to develop their programming skills requires curriculum support with handout information about turtle primitives, along with examples of programming procedures. The teacher provides the scaffolding and guided questions to support student development of workable program procedures. Students can approach programming using a top down strategy (in other words, writing code directly into programs and testing outcomes in the Command Center) or bottom up strategy (students test parts of the program in the Command Center and paste pieces of workable code into program procedures). Teachers will find themselves learning with the students as they discover innovative ways to use and apply program procedures. Since teacher time is usually limited, students should learn to debug procedures, for instance, by testing code line-by-line and working with student teams to solve their problems.

Additional experience teaching Logo coding using MicroworldsEX and the e-book was developed providing instruction to high ability elementary and middle school students for an Early Outreach Program (EOP) at Iowa State University. It was found working with this population, particularly middle school students, Logo coding project development showed advanced graphic designs and included interactive games. Some examples of project ideas developed by students are listed in Figure 4.

Graphic Program Projects

- Graphic design using a slider tool
- International flag program with button coding procedures
- Rubic cube program
- Sailboat graphic with random color sails
- Mobile phone graphic design

Game Program Projects

- PS4 game controller interactive words and lists
- Turtle invader game design procedure
- Survey quiz using buttons for answering trivia questions
- Pong game with animated moving ball
- Coin flip program
- Moving chessboard pieces with reset button
- Turtle animation race
- Hide and seek with trivia game

Figure 4. EOP Middle School Turtle Graphics and Project Games

In 2020 LCSI upgraded the Logo coding program to a cloud-based platform. During this time the MicrowoldsEX e-book was revised for use with Lynx. Edits, updates, and additions included a research article on teaching Logo coding, animation procedures, and using interactive words and lists for developing games. A final section of the text suggests examples of interactive games to review at the Lynx website. The e-book *Exploring Computer Science with Lynx* (Walsh 2020) is downloadable at LCSI @ https://lynxcoding.club/. The MicroworldsEX and Lynx e-book have been available for the Canada Cancode 1.0 and 2.0 programs launched in 2017 and renewed in 2019 providing $110 million in federal monies. CanCode 3.0 will receive $80 million in 2021. The programs are providing support for kindergarten to grade 12 students, with teacher training, in digital skills to prepare for future jobs.

Future Research Directions

Logo was discussed as a coding language with the potential to achieve cognitive benefits. These benefits are given when more carefully planned teacher-directed lessons are balanced with student problem solving and planned discovery using teacher-mediated scaffolding. Support for more carefully planned, teacher-directed lessons during initial introduction and learning of Logo skills is provided in the literature. *Exploring Computer Science with Lynx* provides a curriculum methodology for teacher delivery of Logo coding skills to students balancing teacher direction with planned discovery. Teachers will need to serve as facilitators to provide student support by scaffolding student questioning and directing independent Logo programming exploration. More research will be needed on specific teacher mediation intervention techniques, in addition to better understanding what is required to facilitate successful transfer of problem-solving skills from Logo to other domains including coding in different languages.

Conclusion

Empirical and meta-analysis research studies support of teaching Logo programming in developing student cognitive problem-solving skills has been documented. Using guided instruction with teacher-mediated scaffolding has been found as an effective method in preparing students using the Logo code programming language to create geometric graphic, animation, and gaming projects. Anecdotal classroom benefits in teaching coding have been found along with research on Logo's contribution to student learning. Research on potential benefits, using teacher-mediated or guided instruction is discussed along with curriculum methodology for teacher delivery of Logo coding skills to students balancing teacher direction with planned discovery. Teacher scaffolding strategies are presented including cognitive monitoring. Anecdotal student benefits learning Logo coding in the classroom along with differential instruction outcomes have been presented. Hopefully, opportunity to teach Logo instruction using the Lynx program will be provided to enthusiastic coder learners in the future!

Acknowledgements

The author as a classroom teacher providing instruction in Logo coding acknowledges with appreciation the students at the elementary and middle school level in supporting his learning of Logo and gaining insight into their strategies using coding skills. Recognition is also given to my major Professor Dr. Ann Thompson who inspired interest and facilitated research work at Iowa State University in Logo programming contributing to development of the curriculum e-books.

References

Alfieri, L., Brooks, P. J., and Aldrich, N. J. and Tenenbaum, H. R. (2011). Does discovery-based instruction enhance learning? *Journal of Educational Psychology* 103 (1), 1-18.

An, E. (2017). 7 benefits you'll notice when you start learning to code. *CareerFoundry*. https://careerfoundry

Bureau of Labor Statistics. (2021, September 6). *U.S. Department of Labor, Occupational Outlook Handbook*, *Computer Programmers.* https://www.bls.gov/ooh/computer-and-information-technology/computer-programmers.htm

Heggart, K. (2014). Coded for success: The benefits of learning to program. *Edutopia*. https://www.edutopia.org/discussion/coded-success-benefits-learning-program

Innovation, Science and Economic Development Canada. (2021, December 2). Government of Canada launches third phase of CanCode Program targeting 3 million training opportunities for youth. https://www.canada.ca/en/innovation-science-economic-development/news/2021/07/government-of-canada-launches-third-phase-of-cancode-program-targeting-3-million-training-opportunities-for-youth.html

Khormi, S., Alshoshan, A. and Binrsheed, A. (2021, September 6). The impact of using Logo programming language on the development of spatial visualization ability among elementary school students. *International Journal of Research*. 9 (3), 118-127. https://www.granthaalayahpublication.org/journals/index.php/granthaalayah/article/view/IJRG21_A03_5173

Lee, M. (1990). Effects of Guided Logo Programming Instruction on the Development of Cognitive Monitoring Strategies Among College Students. Unpublished PhD dissertation, Iowa State University.

Littlefield, J. Delclos, V. R., Bransford, J. D., Clayton, K. N. and Franks, J. J. (1989). Some prerequisites for teaching thinking: Methodological issues in the study of Logo programming. *Cognition and Instruction* 6 (4), 331-366.

Logo Foundation (2015). Logo and learning. https://el.media.mit.edu/logo-foundation/what_is_logo/logo_and_learning.html

Morris, S. (2021, August 15). 8 ways learning to code can benefit you right now. *Skillcrush*. https://skillcrush.com/2017/01/30/learn-to-code-benefits/

Papert, S. (1980a). Mindstorms: Children, Computers, and Powerful Ideas. New York: Basic Books, Inc. Publishers.

Papert, S. (1980b). New cultures from new technologies. *Byte*, 5 (7), 230-240.

Papert, S. (1999). Logo philosophy and implementation. Article: What is Logo? And Who Needs It? http://www.microworlds.com/company/philosophy.pdf

Pardamean, B. and Teddy Suparyanto, E. (2015). Improving problem-solving through Logo programming language. *The New Educational Review* 41 (3), 52-64. https://www.semanticscholar.org/paper/Improving-problem-solving-skills-through-logo- PardameanSuparyanto/db1a0857c61235df653a406d1f077ff1ba41b52a

Porter, J. (2021, September 7). 4 benefits of learning programming at a young age. *ELearning for Kids*. https://elearningindustry.com/4-benefits-learning-programming-at-a-young-age-2

Walsh, T. (1992-93). The implementation and evaluation of a sequential, structured approach for teaching LogoWriter to classroom teachers. *Journal of Educational Technology Systems*. 21 (4), 343-362.

Walsh, T. (1994). Facilitating Logo's potential using teacher-mediated delivery of instruction: A literature review. *Journal of Research on Computing in Education*. 26 (3), 322-335.

Walsh, T. (2013-2017). *Exploring Computer Science with MicroworldsEX.* Montreal Quebec, Canada: Logo Computer Systems, Inc. (LCSI).

Walsh, T. (2020). *Exploring Computer Science with Lynx.* Montreal Quebec, Canada: Logo Computer Systems, Inc. (LCSI). https://data.lynxcoding.org/help/en/Exploring%20computer%20science.pdf

Williams, J. (2021, September 7). 10 surprising skills kids learn through coding. *We Are Teachers*. https://www.weareteachers.com/skills-learn-coding/