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Using Coding to Positively Impact Writing in the Elementary Classroom

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Using Coding to Positively Impact Writing in the Elementary Classroom

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Chapter I: Introduction

According to Graham et al. (2017), “writing is an extremely challenging task” in the best of circumstances. For students who struggle with reading, writing is kryptonite for many, a trigger topic that feels impossible to tackle and without purpose. Research (Graham et al., 2017) on the correlation between writing quality and motivation found that motivation plays a statistically significant role in writing quality as well as quantity (word count). For many students writing can seem like an insurmountable task that requires unnecessary time and energy. The goal is to find a way to build purpose, engagement and motivation into the task of writing for the students who struggle.

This paper will explore several studies that have been conducted in the primary grades as they examine the concept of motivation and writing and the relationship coding plays on both. Research by Fenty et al. (2021) as well as Thompson et al. (2017) has shown that from early childhood classrooms to focused interventions with dyslexic students, the issues of purpose, engagement and motivation are no longer insurmountable barriers when coding was integrated into the curriculum. With the addition of coding, students were able to find the power of self efficacy regarding their literacy education (Thompson, et al., 2017).

Extensive research from Hassenfeld and Bers (2020) demonstrates that coding helps students who struggle feel engaged and motivated to write in a multimodal form and then take that confidence and transfer it toward writing. Further research by Karas et al. (2021) suggests that there is a natural neurological transfer that occurs between coding and writing as the two share parallel processes.

Equally important in the link between coding and writing is equity. In many states in the US, coding fluency is viewed as having a second language for the 21st century (Fedorenko et al., 2019). Having the skill to understand computer language and be able to code would level the playing field for many underserved student populations.

The purpose of this starred paper is to explore the influence of multimodal literacies on motivation as it relates to writing performance and engagement. Coding, or computer programming in particular will be examined in the context of a motivating activity as well as a parallel literacy. While the two terms of coding and programming are not synonymous, they were often used interchangeably in articles. To simplify, when referring to computer programming or coding, the term coding will be used. Chapter I will discuss current research regarding the significance of the study. Chapter II will view the concept of using coding to strengthen literacy, specifically in the context of the early childhood classroom and for students with special needs. Chapter III will touch on some limitations of the research cited in this paper, as well as detail the specific research referenced in this paper.

The writing process

Using code for multimodal writing employs many of the same theoretical underpinnings of traditional writing. In early childhood, concepts of print are fostered through the left to right method of coding (Delacruz, 2020). Students in the early childhood settings are also able to work on retelling stories through coding (Fenty et al., 2021). The subset of activities used in writing and coding are parallel, from the initial planning/prewriting stage to the debugging/revision stage

(Hassenfeld & Bers, 2020). In addition, young programmers use the five stages of story structure (exposition, rising action,climax, falling action, resolution) to write code (Delacruz, 2020), enriching the process they bring to their written narrative. Overall, the writing stamina, development of ideas, even the word count of students writing has been seen to make significant growth after working with coding platforms (Thompson & Childers, 2021).

Equity

Equity in education is an essential issue to be discussed in every discipline, from mathematics to language arts. With experts anticipating that jobs in the STEM field will grow faster than any other field in the next decade (Tran, 2018) it is of immediate concern that there is equity in computer science. Coding is in a unique position as the essence of what it is and where it belongs is being debated, the opportunity for systematic inequalities arise. Coding allows students to "learn specialized language and exposes them to the types of reading and writing performed in professions involving computer programming of any kind" (Hutchison et al., 2015). It is suggested that coding could soon be considered a fundamental literacy, one in which students need to be fluent for the jobs of the future (Hutchison et al., 2015).

According to the latest research from Warner et al. (2022) in which they utilized the CAPE Framework (Capacity, access, participation, and experience) "less than half of the high schools in the country currently offer CS (computer science) courses" (p.2). Information gathered from Code.org, CSTA and ECEP Alliance found that schools with 75% of their students on a Free or Reduced meals had only a 34% chance of having CS classes (Warner et al., 2022,

p.4). There is also a significant disparity between male and female participation in computer science as demonstrated by a 2020 State of Computer Science report that showed that "nationally, over twice as many male than female students took the AP CS exam" (Warner et al., 2022, p.5). As stated by Warner et al. (2022), "researchers have consistently found disparities in terms of who participates in CS, with CS course and exam enrollment rates tending to be lower for students who are female, economically disadvantaged, or racially minoritized" (p.11). It is essential that the nature of coding as a computer science be defined and integrated into the education of each student.

Research Question

What is the impact of coding on writing in the elementary classroom?

The Significance of the Study

Much of the research regarding the relationship between coding and literacy is new, but the theory is growing in momentum. Coding itself has been, for the most part, considered a STEM subject, but researchers are questioning whether it would be more beneficial for programming to be enfolded into ELA. Federal legislation has provided grants to schools who add Computer Science into their mathematics or science. However, some states are enfolding coding as a 2nd language requirement. As of 2019, 33 states have put coding into the math/science realm, while two states view it as fulfilling a 2nd language (Fedorenko et al., 2019). The issue, as Fedorenko et al. (2019) see with these policies is the lack of research behind them. As coding is done on a computer, it was naturally and without being backed by research,

placed into the science and technology realm. As Fedorenko et al. (2019) asserts, that in order for the curriculum, assessments and interventions needed to still be put in place for coding, the cognitive processes must first be investigated and understood. The research presented in this paper considers the theory of Coding as Literacy (CAL), a term developed by researcher Marina Bers (Hassenfeld et al., 2020) in the primary grades.

Key Terms

Table 1

Key Terms & Definitions

TERM	DEFINITION
Coding	"Step-by-step instructions on how to complete a task" (Hutchison et al., 2015, p. 494). In the context of this research, coding is used interchangeably with programming.
Computer Programming	The process of writing directions for a computing devices and systems (Carlton, 2021)
Coding as Literacy (CAL)	Term developed by Marina Bers as a "system of communication, natural or artificial, composed of a formal system of signs, governed by syntactic and grammatical combinatory rules, that serves to communicate meaning by encoding and decoding information" (Hassenfeld et al., 2020, p.68)
Multimodal Literacy	Using two or more modes to communicate meaning in a text (Thomas, 2012)
Semiotic Modes	Written-linguistic, visual, audio, gesture systems for making meaning (Vincent, 2007)
Kokopelli's World (KW)	Sentence blocks-based computer coding program (Thompson & Childers, 2021)
Scratch Jr	Block-based computer coding program (Hutchison et al., 2015)
Kahootz	3D animation software computer program (Thomas, 2012)

Google CS First	Block-based computer programming curriculum (Burke et al., 2016)
KIBO	Robotics kit with wooden coding blocks (Lee & Junoh, 2019)
Story-Writing-Coding (SWC)	Text-based computer coding program (Price & Price, 2018)
MicroWorlds	A multimodal program that uses the computer programing language, LOGO (Vincent, 2007)
STEM	Science, Technology, Engineering & Math

Chapter II: Review of the Literature

The purpose of this study is to review current research regarding the effect of coding in the language arts, specifically the field of writing. The background information and importance of the study was introduced in Chapter I. This chapter will go into further detail on several research studies which examined the link between coding and writing in the early childhood and elementary classroom. Specific research regarding special education and early childhood will be elaborated upon.

How Coding Strengthens Literacy

One of the founding fathers of Computer Scientist, Seymour Papert, a noted pioneer in the constructivist movement in education had a theory which stated that "the best way to ensure that knowledge is built in the learner is through the active construction of something shareable — a poem, program, model or idea" (Stager, 2016, para. 5). As Hassenfeld et al. (2020) explains, Papert felt that "the true power of computer science education was providing students with a new medium for expression and communication" (p.68) executed through the use of coding.

The Coding as Literacy (CAL) approach goes back to Paperts original vision of using coding as a way of expressing ideas and communicating. (Hassenfeld et al., 2020). Researchers, Hassenfeld et al., looked at using a CAL curriculum with the KIBO block based robotics kit. Within the CAL-KIBO (CAL-K) curriculum, each coding concept had a coinciding literacy element interwoven (Hassenfeld et al., 2020).

Research using the CAL-K curriculum suggests that coding strengthens literacy development for all learners (Hassenfeld et al., 2020). The article, *If you can program you can write: Learning introductory programming across literacy levels,* follows a pilot program in a "complex" school district in Virginia, specifically with the 2nd grade students (N=132) across

thirteen classrooms. Teachers were trained in the CAL-KIBO curriculum and implementation was tracked across 12 hour long lessons over the course of six weeks. The screening tool, PALS, was used to identify students at risk. The KIBO mastery challenge (KMC) was used during four intervals to measure KIBO mastery of the programming language and concepts (Hassenfeld, 2020).

> Aligning with the increasing difficulty of subsequent lessons, the later assessments were designed to be harder than the earlier ones due to the content of the curriculum. In order to ascertain precise question difficulty, we used item response theory to calculate each question's difficulty index. The difficulty index was used to calculate a weighted score for each question reflective of this population, with more weight being given to more difficult questions. Once weighted, each student's individual KMC scores were summed to obtain a single composite score (Hassenfeld et al., 2020, p.74)

To examine the relationship between students' literacy abilities and their composite KMC score they used the Bayesian linear regression using the BayesFactor. They included teachers as a random factor to counter the possible impact of individual teachers.

The BeyesMed package showed very strong evidence for a positive but weak correlation between the PALS scores and the composite KMC scores. The researchers find this result significant as the students from all literacy levels were able to master the programming language, teachers could use programming to strengthen literacy development.

There are limitations with their findings in Hassenfeld et al., (2020) research, particularly with the premise of higher achieving students generally scoring higher in multiple domains. The researchers also wondered if the language focused curriculum also led to an overall increase in literacy levels. Concepts such as audience and story structure are found to be enhanced with the

narrative aspect of the programming curriculum. This research furthers the idea that programming builds motivation for many students who struggle with reading and writing to creatively tell a narrative in a different format. More importantly this research demonstrated that the use of a programming curriculum such as the CAL-K reinforced important early literacy components of prewriting, drafting, editing and revising in an engaging and positive way.

In the article: “The Impact of Learning to Code on Elementary Student’s Writing Skills,” researchers Jane Thompson and Gina Childers (2021) looked at Google's CS First Storytelling Lessons. They believed that the collaborative nature of this specific coding curriculum would allow students to think critically and creatively while building skills essential in ELA. This specific program was chosen for its clear and consistent instructions which allow the research results to be transferable regardless of the instructor. They asked: “Does learning to code through CS First’s Storytelling lessons impact the development of elementary grades students’ writing skills, writing stamina, and perceptions of writing abilities?”

This study used Quantitative Data collection in the form of pre and post writing assessments and as well as the Mississippi Academic Assessment Program English Language Arts Writing Rubric. To analyze the data they used Statistical Package for Social Sciences software. Their findings demonstrated a significant impact on overall writing scores, development of ideas and writing organization. There was also a significant increase in the writer's stamina as demonstrated by a word count analysis. In a post interview with 10 students (part of their qualitative data collection) they observed an increase in confidence and motivation among the students. They did not see a significant change in the mechanics of writing or grammar.

The compositional activities of writing and coding are similar, (planning and prewriting aligning, creating and drafting, testing and evaluating, debugging and revising) though students' response to each step may prove to be quite different (Hassenfeld & Bers, 2020). In "Debugging the Writing Process: Lessons From a Comparison of Students' Coding and Writing Practices" the study claims that the issue of purpose and audience with emergent writers makes editing and revision a difficult task in writing, whereas debugging in coding is an activity students feel motivated and engaged in (Hassenfeld & Bers, 2020). Researchers Hassenfeld and Bers conducted a four-month ethnographic-interview study of second grade students. Their sample size was markedly small (three students of varying literacy levels) and should be noted.

Both writing and coding are a sort of "initiation into composition, the activity of creating an artifact that communicates explicit meaning, meaning that can travel away from the author and even be understood entirely independent of the author. They both involve planning, writing, evaluating, and editing and revising" (Hassenfeld & Bers, 2020, p.745). Their findings demonstrate a marked distinction between the motivation and efforts to edit and revise in coding vs writing. They argue that writing and coding should be taught to tell a shared narrative to increase students' motivation for the revision process in writing. The evidence from this study would suggest that while the two share similar processes, proficiency and motivation with one does not implicitly transfer to the other. The researchers would suggest linking the two, rather than viewing each in isolation.

Researchers Hutchison, Nadnony and Estapa (2015) (coming from a background in literacy education, technology education and mathematics education respectively) claim that "coding apps can be used to support literacy instruction and to develop digital and disciplinary literacy skills in the classroom." (p.494) To prove their claim they highlighted coding games that

provide problem solving opportunities while learning content-specific vocabulary. They also point to the idea of coding to learn in spaces where "they learn how to create and express themselves with the computer, not just to interact with it" (Hutchison et al., 2015, p.496). The article points to CCSS.ELA Literacy standards that are practiced while using the coding game, Scratch (see Table 2 below).

Table 2

Compiled from information in the article, "Using Coding Apps to Support Literacy Instruction and Develop Coding Literacy" by Hutchison et al. (2015)

Strategies/Steps used in Scratch	CCSS.ELA Literacy Standards
1. Inventing and scripting a creative idea for an original game 2. Writing directions that tell how to play the game	Produce clear and coherent writing in which the development, organization and style are appropriate to the task, purpose and audience
1. Remixing, a feature that allows users to learn from, interact with, and add on to the work of others 2. Commenting option to allow students to comment on designs	Prepare for and participate effectively in a range of conversations and collaborations with diverse partners, building on other's ideas and expressing their own clearly and persuasively
Using programming logic to create the code that will make the game work	Acquire and accurately use a range of general academic and domain specific words and phrases sufficient for reading, writing, speaking, and listening at the college and career readiness level

The article also discusses the use of *if-then relationships* as well as learning to read and write domain specific vocabulary as they creatively sequence events to move their narrative along. With the research of Hutchison et al, (2015), the primary source of demonstrating that coding can benefit literacy instruction is through secondary integration ideas in which case could be incidental.

In the article, *Starting From Scratch (Jr): Integrating Code Literacy in the Primary Grades,* Stacy Delacruz, (2020) states that "using ScratchJr in content area literacy instruction is a viable option to help engage students in demonstrating what they have learned in other subject areas while also helping them learn to code at a young age" (p.810). She also provides additional strategies for teachers to implement CAL into the classroom with a 5 step outline (p.806):

Step 1: Introducing Students to Coding Using ScratchJr (suggests printing coding block resources to provide visual supports for English learners)

Step 2: Select the Standards and Text (websites for articles are provided)

Step 3: Organize the Draft Project (suggests using a graphic organizer & shows sample student work)

Step 4: Coding the Project (cursory introduction to the steps involved in coding with ScratchJr)

Step 5: Evaluate the project (sample rubric provided). She points to correlations between coding and literacy suggesting that literacy standards are embedded into coding

Findings demonstrated that overall students were more motivated and engaged in their learning as they were pushed to think more critically with the coding activity, "promoting their literacy skills of concepts of print, fluency and comprehension" (Delacruz, 2020, p.809).

Coding as Literacy in Early Childhood Classrooms

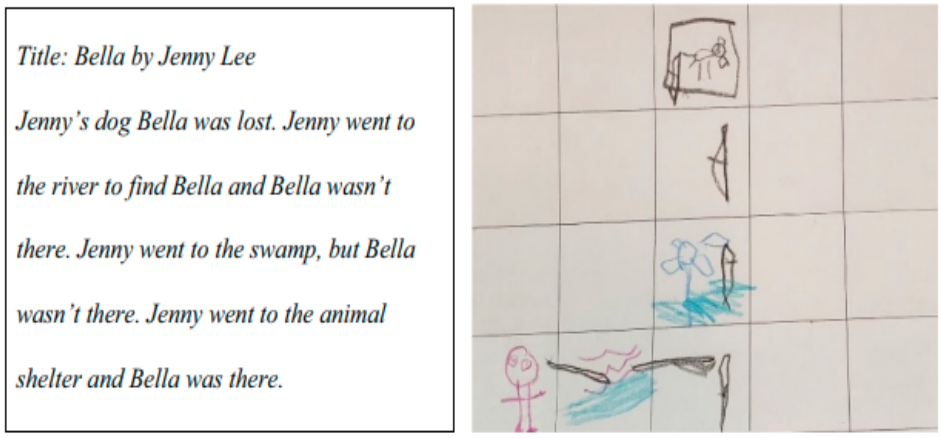
Researchers Monteiro et al. (2021), collected five months of field data on preschool children working with specific elements in coding, analyzing possible ways in which coding can be integrated into various domains. While this was a multidisciplinary study, their findings showed that young children primarily use coding as a form of expression and communication .

Further research looking at integrating Coding as Literacy (CAL) into inclusive early childhood classrooms found that unplugged precoding activities may have a “reciprocal positive relationship with literacy” for young students with needs (Fenty et al., 2021, p.277). They pointed to the Language and Literacy domain of the Head Start ELOF and found the Communication and Speaking domain to be formatted to accompany coding (Fenty et al., 2021). In each of these studies, student engagement and motivation were mentioned as positive outcomes.

Additional research by Joohi Lee and Jo Junoh (2019) assert that the primary focus when looking at coding in early childhood classrooms is in making it developmentally appropriate and unplugged (Lee & Junoh, 2019). They recommend the use of hands on manipulatives when building code. They also suggest the integration of children's books into the coding process. To further build upon the literacy and coding skills they strongly recommend young children create their own stories in the coding format. See figure 1 (below) as a sample original story by a 4 year old student learning to tell a narrative in a sample coding format. Lee and Junoh (2019) also point to the intentional use of coding-based vocabulary when doing routine tasks, such as washing hands or tying shoes. In doing so, students will build a deep background of this specific academic language. They find that in addition to building vocabulary, children are able to learn sequencing skills, a precursor to quality writing.

Figure 1

From "Implementing Unplugged Coding Activities in Early Childhood Classrooms" by Lee & Junoh (2019, p.715).



Coding as Literacy for Students with Special Needs

In the article, "Writing and coding: Assisting Writers to Cross the Modes," Vincent (2007) examines the transmediation process, in particular, with at-risk children who find verbal text production difficult. With the at-risk students, the ability to communicate via multimodal text brought increased confidence and narrative storytelling. When allowed to use the multimodal platform of Microworlds (which uses the LOGO coding language) the same students were able to increase their text production (see Figure 2 below). Conversely, the highly skilled writers felt inhibited by the multimodal platform. The article claims that the struggling students did not have the necessary processing to create mental imagery, which was a contributing factor in their struggle to write. When presented with a visual literacy, and "having a concrete realization of the other modes, they became absorbed, totally focused and produced integrated high-quality multimodal texts." (Vincent, 2007, p.149) It is important to note however, that for the students who were identified as skilled writers, the multimodal activity stinted their creative

storytelling. The researcher discovered that while coding may be a motivating and engaging platform for writing for one student, using it as a writing platform may prove to be stifling for another.

Figure 2

From "Using Coding to Positively Impact Writing in the Elementary Classroom" by Vincent (2007, p.147)

Peter's final draft of a reflective writing prompt above.

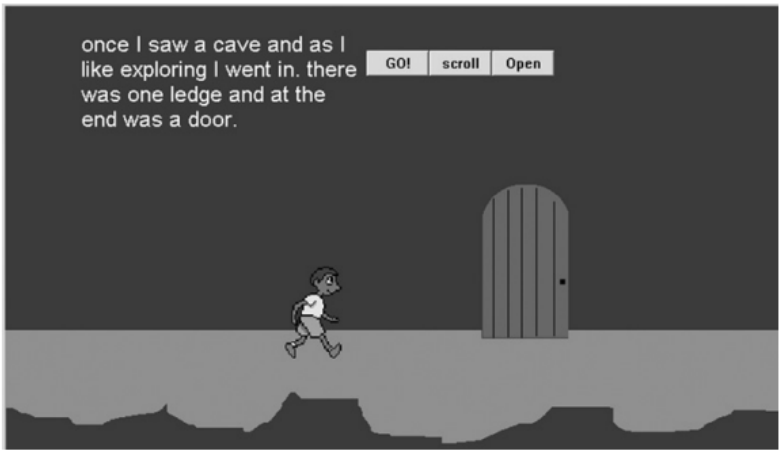


Figure 2 Peter: Screen 2 of five-screen narrative from a multimedia text composed with MicroWorlds

In another study coding was not used as an alternative to writing, but rather an additional intervention for students with dyslexia (Thompson et al., 2017). Over the course of 12 two-hour sessions held once a week the students engaged in the Human Assisted Writing Knowledge (HAWK), a computerized intervention system. In addition to this program, which had been proven effective through earlier research, hope stories were also incorporated, as well as coding lessons. As previous research demonstrated coding can be advantageous to students with learning disabilities, Thompson et al. (2017) proposed that using coding for students with dyslexia would provide a hands-on approach to engage the students. Their findings demonstrated

that there was an improvement at the syntax level for both reading & listening comprehension, written composition and oral expression. The teachers observed that there was also a marked increase in student motivation with the addition of coding.

The computer program used for coding was Kokopelli's World (KW). In KW the students used a sentence structured block-based programming to tell their stories sentence by sentence. The primary limitations are due to the design experiment method that was used. As there were multiple components used in this intervention, further research needs to be done to be able to pinpoint the specific impact of adding coding and hope stories. Despite these limitations, this research furthers the idea that programming has a positive impact on motivation and engagement for students with learning disabilities. It also demonstrated a positive effect on overall literacy at the syntactic level. While it didn't show a direct positive impact on specific writing strategies, the evidence of motivation and engagement is compelling, particularly as these are two pieces that are primary obstacles with writing, primarily in the revision/editing process.

Limitations

The primary limitations with researching the benefits of coding on writing lie in the ideal of coding as literacy. While the theory has positive research behind it, it is still in its infancy. The bulk of research on coding lies in the STEM field, with very little attention examining the correlations within ELA. As it is a new theory, the accompanying research is not only limited, but led by a small number of researchers who may or may not be unbiased.

In addition, there is the issue of having a wide expanse of coding software designed specifically for young children. Of the fifteen articles researched in this paper, six different software coding programs were mentioned, each carrying their own strengths and unique

limitations. Three of these programs were language based while the other half were block-based coding programs. Further research needs to be done to analyze if there is a marked difference between the relationship with writing and coding as it relates to sentence based coding or the popular block-based introductory method. The research findings of Monteiro et al. (2021) noted issues with limited resources for the preschool students in their study. Perhaps it was due to the lack of resources that student motivation and engagement became an issue within this particular study, though it could also point to the significance earlier recommended, of implementing unplugged coding activities in preschool settings rather than having students on devices.

In some of the studies, the integration ideas that were presented, while interesting and potentially helpful, are not able to demonstrate that the coding apps do *support* literacy instruction. This information is not enough to warrant the claim that coding apps develop disciplinary literacy skills. Neither do all the articles strengthen the question of there being a positive correlation between the writing and coding. The research does however demonstrate that there are similarities between the two, and that by engaging in coding, it could support the work of literacy, particularly if the teacher plans and implements secondary literacy lessons.

Summary of Research

Seventeen articles were used as the basis for the research in this paper. They are noted below in order of publication date. The articles published in the same year are listed alphabetically. The study design, participant demographics and article findings are described in the table 3 below.

Table 3

Summary of Research

Authors	Study Design	Participants	Findings
Vincent, J. (2007)	-Correlational Research -Multimethod research using qualitative data from student work and extensive student interviews, examine relationship between multimodal scaffolding and writing -Integrate coding platform MicroWorlds into writing	26 Grade 5 students in Melbourne, Australia	-Multimodal communication improved confidence and narrative writing with at-risk students -High achieving students found platform limiting -Students who had difficulty writing lacked ability to create clear mental image -integration of coding and writing allowed students to cross semiotic modes
Thomas, A. (2012)	-Correlational Research -Examine how multimodal authoring impacts communicating literary concepts -Qualitative Data collection from student work using Kahootz & student interviews	Two 6th grade classrooms in Tanzania, Australia	-Students demonstrated a strong sense of communicating to an audience & point of view -Students were able to create narratives using multimodal literacy with image, verbiage and sound -Student motivation was high
Hutchison, A., Nadolny, L., & Estapa, A. (2015)	-Descriptive Research -Advocates Coding as Literacy -Suggests idea of using Coding to Learn	N/A	-Coding enhances informational text with building understanding of "If-then" relationships -Coding builds specialized academic vocabulary -Reading/Writing activities suggested to integrate coding into literacy -Integration ideas for Scratch & CCSS-ELA
Burke, Q., O'Byrne, W. I., & Kafai, Y. B. (2016)	-Descriptive Research -Coding allows participation in 21st century literacy skills	N/A	-Coding builds literary themes of audience and process -Writing workshop model for teaching programming

			language -Ability to code allows students to compete with 21st century literacy skills
Graham, S., Kiuhara, S. A., Harris, K. R., & Fishman, E. J. (2017)	-Holistic scoring procedure of pre & post personal narrative samples including word count -Student self-reporting scale was used -Confirmatory Factor Analysis was used to check controls -Hierarchical regression analysis to test if motivation & strategic writing behaviors made separate contribution	227 4th Grade Students	-The role of motivation played a statistically significant role in writing quality
Thompson, R., Tanimoto, S., Lyman, R. D., Geselowitz, K., Begay, K. K., Nielsen, K., Nagy, W., Abbott, R., Raskind, M., & Berninger, V. (2017)	-Design experiment method with Multi-component intervention system: (HAWK Letters in motion, HAWK words in Motion, HAWK Minds in Motion & Kokopelli's World coding program) -Qualitative data from pretest & posttest analysis -12 two-hour lessons	4th-6th grade students with persisting dyslexia	-Increased engagement & motivation -Improved self efficacy -Significant improvement in decoding and spelling, syntax skills, reading comprehension -Can not definitively point to coding as the contributing factor for student improvement
Price, C. B., & Price-Mohr, R. M. (2018)	-Correlational Research -Year long mixed-mode approach to data collection of children's code looking for commonalities in how story meaning was expressed -Observational data & student interviews analyzed by Systemic Functional Theory	103 children (5-11 years old) 39 from rural schools 34 from inner-city schools 36 from public event held at library	-Students were able to express stories with coding using the outline-first or the interactive strategies -Limited language use in coded writing as the Story Writing Coding (SWC) language is restricted
Tran, Y. (2018)	-Exploratory Mixed-Method study using pre & post testing -10 week coding program using Blockly coding language	200 elementary students	-96% of students had positive reactions to coding -Students identified persistence as essential

			-Lack of resources & teacher knowledge with underserved populations
Fedorenko, E., Ivanova, A., Dhamala, R., Bers, M.U. (2019)	-Descriptive Research -Hypothesize parallels between programming and natural language and suggests there are overlapping processing systems -Coding as Literacy approach	N/A	-Suggest further research looking at programming as a literacy rather than STEM
Bers, M. U., González-González, C., & Belén Armas–Torres, M. (2019)	-Multimethod research using qualitative and quantitative research with teacher journals, direct observation & focus groups -3-5 sessions/group lasting 45 min to 75 min each	172 3-5 year olds across 3 Spanish early childhood centers	-Through the integration of coding, collaboration, creativity & communication were promoted
Lee, J., & Junoh, J. (2019)	-Descriptive research used to provide developmentally appropriate guidelines for implementing coding in early childhood classrooms	N/A	Recommendations for coding in early childhood: -Play based & hands-on -Intentional use of coding-based vocabulary -Connecting coding with daily routine (ex: tying shoes) -Integrating literature and children's own stories
Delacruz, S. (2020)	-5 step outline on how to implement coding into the classroom: Step 1: Introducing Students to Coding Using ScratchJr (suggests printing coding block resources to provide visual supports for English learners), Step 2: Select the Standards and Text (websites for articles are provided) Step 3: Organize the Draft Project (suggests using a graphic	2nd grade classroom	-Students were more motivated & engaged, pushed to think critically with the coding activity, “promoting their literacy skills of concepts of print, fluency and comprehension.” (p.809) -five-stage story structure (scene, tension, climax, falling action, resolution) found in both writing and coding. (p.806) Using this

	organizer & shows sample student work) Step 4: Coding the Project (cursory introduction to the steps involved in coding with ScratchJr), Step 5: Evaluate the project (sample rubric provided).		process in a multimodal format provides additional review of strategies for students which would seem to be beneficial for all
Hassenfeld, Z.R. & Bers, M. U. (2020)	-Four-month ethnographic-interview study of second grade students	three second grade students of varying literacy levels	-Writing & Coding share subset of activities as compositional processes of planning (prewriting), creating (drafting), testing/ evaluating (evaluating), Debugging: mechanics (editing), Debugging: stylistic (revising) -distinction between the motivation and effort regarding the editing and revision process in coding vs writing (proposed theory of difference with feedback, audience, and purpose)
Hassenfeld, Z. R., Govind, M., de Ruiter, L., E., & Bers, M. U. (2020)	-12 hour long lessons over six weeks. Screening tool, PALS, used to identify students at risk. The KIBO mastery challenge (KMC) was used during four intervals to measure KIBO coding mastery of programming language and concepts -Correlational study to examine the relationship between coding and literacy abilities using composite KMC score, the Bayesian linear regression using the BayesFactor.	132 second grade students from 13 classrooms	-BeyesMed package showed very strong evidence for a positive but weak correlation between the PALS scores and the composite KMC scores -Result significant as students from all literacy levels were able to master programming language -Suggest teachers use programming to strengthen literacy development

	-used the Coding as Literacy (CAL- KIBO curriculum)		
Fenty, N.S., Pierce, A., & Schildwachter, J. (2021)	-This study provided strategies for implementing precoding activities in an early childhood classroom: 1: Make Connections to Everyday Routines and Procedures Through Explicit Instruction and Peer-Mediated Activities, 2: Make Connections to Read-Alouds Through Explicit Instruction and Peer-Mediated Activities, 3: Consider Literacy Standards (Connecting to Everyday Routines and Procedures), (Connecting to Read-Alouds). Samples and suggestions are provided in article	Inclusive, pre-K classroom	-Precoding activities can be integrated successfully into an inclusive early childhood setting -States that 21st century skills of precoding are not being offered to early childhood students with disabilities
Karas, Z., Jahn, A., Weimer, W., & Huang, Y. (2021)	-The study analyzes an existing medical imaging dataset and compares the neural pathways made with code writing and prose writing using *Functional Connectivity Analysis*	Reused raw fMRI scan data from study by Kruger et al. involving 6 females and 16 males between the ages of 19-25	-Regarding semantics processing and higher mathematics there is a significant interconnection between code writing and prose writing -”Significant functional connectivity between two left temporal regions involved in semantic processing. This evidence again suggests coding relies on similar processes as natural language” (p.10)
Monteiro, A. F., Miranda-Pinto,	-Multimethod research using qualitative data from data collected through activity	Case study for preschool 11 preschool	-The methodology of coding integrates naturally into preschool regarding

M., & Osório, A. J. (2021)	logs, field notes, photos and video recordings -Field observations of 6 sections using Likert scale -Thematic analysis	educators & 17 elementary in 8 Portuguese districts	expression and communication activities -Coding provides natural scaffolding for patterning -Children were enthusiastic -Limitations due to wide variety of coding programs designed for elementary students
Thompson, J., & Childers, G. (2021)	-Google's CS First's Storytelling lessons Quantitative Data collection in the form of pre and post writing assessments -Mississippi Academic Assessment Program English Language Arts Writing Rubric for quantitative data analysis -Statistical Package for Social Sciences software to analyze the data -Qualitative Data from post-coding interviews	49 fifth grade students -49% female -51% male -47% Black -22% White -20% Hispanic -11% Multiracial	-Significant impact on overall writing scores, development of ideas and writing organization -Significant increase in writer's stamina as demonstrated by word count analysis -Increase in confidence & motivation -No significant change in mechanics of writing or grammar. -Highest growth in sub-construct: "Ideas are fully developed and details are specific and relevant (p.8)
Warner, J.R., Fletcher, C.L., Martin, N.D., & Baker, S.N. (2022)	CAPE framework to assess equity data regarding computer sciences	N/A	-Fewer than half of all high schools in the US offer computer science courses -Disparity between involvement in computer science courses for economically disadvantaged students, females and racially minoritized

Chapter III: Conclusion

The purpose of this study is to examine the role coding plays in writing and motivation. My research is to examine the relationship between coding and writing. Specifically, what is the impact of coding on writing in the elementary classroom? Overall, the results when incorporating coding into the curriculum were positive. Students from preschool to elementary school felt engaged and motivated to code and the studies showed a positive impact on writing. In Chapter I, background information was provided as to the importance of this study. Chapter II summarized the research findings. In this chapter the specific research will be highlighted and recommendations will be suggested.

Conclusions

To study the impact of coding on writing, Karas et al. (2021) examined raw fMRI scan data. This information was used to study a possible interconnection between coding and writing in the brain. A strong neurological link between brain processing when coding and prose writing was detected. “Finding a significant functionally connected cluster between the NFA and Broca’s area implies the neural basis of coding is intrinsically tied to language process” (Karas et al. 2021, p.7). Using Functional Connectivity Analysis, a neurological link between coding and writing was established.

In The Language of programming: A Cognitive perspective, Fedorenko et al. (2019) suggests further research be done to understand the cognitive processes involved in coding. She suggests a framework to evaluate the natural parallels of coding and language while noting that “a case study demonstrated that knowing a programming language can facilitate the acquisition of reading ability” (p. 526).

Three of the studies looked specifically at coding in the early childhood classroom. Each of the studies found a positive outcome of student motivation as well as a connection to literacy and prewriting.

Monteiro et al. (2021) worked in 8 Portuguese districts with limited resources during the Covid pandemic. They found that coding provided opportunities for expression and communication. Through analysis of field observations, the researchers found that student motivation and perseverance was a positive outcome. They did find frustration with not having enough qualified instructors with "buy in" or hardware for students.

By contrast, Lee & Junoh (2019) encourage unplugged coding for young children. They provide engaging guidelines for educators to implement coding into their classrooms in a motivating and meaningful way which builds sequencing and vocabulary. Both Lee & Junoh (2019), and Fenty et al (2021) suggest coding activities that are linked more to students' lives (ex: tying shoes). They also detail ways to integrate literature into coding activities. The more developmentally appropriate approach to coding suggested by Lee & Junoh is termed "precoding" by researchers, Fenty et al. (2021). Fenty et al. (2021) states that the 21st century skills of precoding are not typically offered to early childhood students with disabilities, but details a plan to successfully integrate coding into an inclusive early childhood setting.

Thompson et al. (2017) also looked at integrating coding for students with special needs. After 12 two-hour lessons they found a significant improvement in decoding, spelling, syntax skills, reading comprehension, engagement and motivation. As there was a multi-component intervention system, the benefit can not definitively point to the use of the coding. It can however, be acknowledged as playing a part in a positive outcome for students, specifically as the students were engaged and motivated to work with the Kokopelli coding software.

The study by Vincent (2007) also worked with students who were labeled “at-risk” academically, as well as high achieving students. Unlike the Thompson et al. study, this research only had one variable-the MicroWorlds coding program. Researchers found improved confidence and narrative writing for at-risk students. For the students who were skilled writers, they found the platform of coding limiting for idea expression.

Price and Price-Mohr (2018) conducted a year-long study that also examined children’s narratives created through coding and then analyzed the information looking for commonalities in how meaning was expressed. They found that students were engaged and motivated, though there was limited language use in their code writing (as the story writing coding language is restricted). After a detailed analysis by Systematic Functional Theory, they argue that “coding be thought of as a form of literacy and that taking this perspective may lead to benefits for children as both literacy learners and also learners of computer programming” (Price & Price-Mohr, 2018, p.2).

Thompson and Childers (2021) used a quantitative data collection in the form of pre and post writing assessments after a summer program with Google’s CS First curriculum. They found a significant impact on overall student writing scores, development of ideas, and writing organization. Using a word count analysis, there was a significant increase in writers' stamina. Using qualitative data from student interviews, their findings also demonstrated a significant increase in motivation and confidence.

Thomas (2012) examined the role of the audience, of particular importance when writing. This study found that through creating multimodal narratives using coding, students had a strong sense of audience. Burke et al. (2016) also found that for young writers the aspect of the audience can seem confusing. They point to coding, as a way of connecting and sharing one's

work, and build the content in writing. They make the comparison of the writing process and the coding process as not only aligning but of being the same. Hassenfeld and Bers (2020), as well as Hassenfeld et al. (2020) also compare the compositional process of writing and coding while Hutchison et al. (2015) and Delacruz (2020) provide ideas to integrate coding into ELA.

Recommendations

There is no question that coding should be implemented with fidelity across the nation's schools to support equity. The question lies with the impact of coding on writing. With the research presented here there is a consistent correlation between coding and motivation. Motivation is an underlying factor in student success in writing, however the two are not implicitly connected. Evidence has shown that there are correlations between the writing and coding processes from neural pathways to an increase in writing production when coding is integrated with literacy.

For myself I have informally examined the correlation between coding and writing in my classroom of 21 second graders, looking specifically at my student who struggled in reading. With implementing 30 minute lessons of Google CS First Storytelling coding for fifteen days I noted a marked increase in confidence with my student who struggles. He was able to create a compelling story with a beginning, middle and ending, clear characters, setting and problem. For this student, the ability to code a creative story, and then go on to help his classmates, gave him the confidence and motivation that are essential in countering the negative mindset that often develops at this young age. Prior to coding, this student would shut down with any reading or writing task, saying, “I can’t do it.” After creating a narrative through coding he now wants to read and write. This experiment built his confidence and motivation in a very concrete and tangible way.

While I saw a significant increase in motivation and confidence toward writing after implementing coding, further research needs to be done analyzing specific coding software, timelines of student access, and buy-in of adult educators, all elements which play a role in the success of any integration for coding as literacy.

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