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Exploring Coding as a Catalyst for Critical Thinking Development: A Case Study in a Private School in Lebanon

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ABSTRACT

This study explores the impact of integrating coding into classroom instruction on the development of critical thinking skills among grade fifth learners in beirut Lebanese. By providing learners with opportunities for hands-on experimentation, collaborative planning, and self-reflection, the study aimed to foster a deeper level of critical thinking. Although the learners initially preferred traditional textbook-based learning, significant improvements in critical thinking were observed in the experimental group (127 learners), demonstrating the effectiveness of an experiential learning approach. The teacher played a crucial role in guiding learners, offering tailored resources, and ensuring that each learner had the opportunity to build knowledge both individually and as part of a team. The study highlights the importance of spreading coding integration across multiple sessions, rather than limiting it to a single weekly session, to maximize learners engagement and learning outcomes such as developing their critical thinking skills. Additionally, the research emphasizes the need for a unified definition of critical thinking skills across the school to ensure systematic development. The findings suggest that coding, when integrated into subject-specific lessons, can develop essential problem-solving and computational thinking skills, making it a valuable tool in primary education. The study recommends further research in both private and public school settings to compare the effects of coding on critical thinking. This research contributes to the limited body of literature on coding's impact within the Lebanese educational context and provides a framework for future studies on skill-based learning and coding implementation.

Keywords: Critical Thinking, Computational Thinking integration, Project based Hands-on Learning, Skill-Based Learning, Teacher Pedagogy.

INTRODUCTION & LITERATURE

Coding and computational thinking in education are not new concepts; they have been taught since the 1960s. However, technological advancements have significantly changed how these subjects are delivered. In today's software-driven world, teaching coding has become essential as it equips learners with Information and Communication Technology (ICT) skills [1]. Modern programming applications primarily use visual programming languages designed to simplify coding instruction, making it more accessible to learners. By reducing unnecessary syntax, visual programming languages help students focus on coding logic and structure, thereby reducing cognitive load [2].

The MIT Media Lab in the United States pioneered the development of Scratch and ScratchJr, which aim to create transformative learning experiences that empower individuals to redesign their lives [3]. These visual programming applications facilitate the development of computational thinking by allowing students to use their native or international language (e.g., English), making the learning process more intuitive.

Research Aim and Research Question

The study aims to examine the effect of coding on fifth graders critical thinking (CT) and provide them with enhanced learning opportunities beyond regular classroom sessions. The research is guided by the following question:

How Does Coding Influence the Development of Critical Thinking Skills in Fifth Graders?

Teaching coding in primary school provides significant advantages over introducing it at a later stage. Early exposure to coding is comparable to learning a new language, as it helps students develop problem-solving strategies, design projects, and generate innovative ideas [4][5]. Furthermore, teachers play a crucial role in integrating coding into real-life contexts by linking classroom instruction with practical applications [6][7].

Recent studies emphasize the importance of introducing coding in primary education, arguing that structured coding instruction at an early age fosters logical thinking and problem-solving abilities [5]. One effective approach is to integrate coding into different subjects through project-based learning, enabling students to see meaningful connections between coding and real-world scenarios. This approach enhances student engagement and improves their ability to sequence logical steps in problem-solving.

Literature Review: Sciences Technology Engineering Mathematics and Computer Science (STEM-C)

A study conducted in Croatia and Puerto Rico aimed to increase K-12 learners' participation in Science, Technology, Engineering, Mathematics, and Computer Science (STEM-C) fields. The research introduced both short-term and long-term programs designed to promote early engagement with STEM disciplines and support students' transition to college.

The Short-Term Program

In K-8 classrooms, introductory science visits exposed students to various STEM fields. These visits included interactive workshops, programming exercises, and participation in the Hour of Code initiative. Additionally, science fairs for grades 9-12 encouraged students to develop research skills, present findings, and receive constructive feedback [8].

The Long-Term Program

For grades 10-12, the study implemented a year-long program consisting of Saturday club meetings and a seven-week summer camp. During these sessions, students engaged in hands-on STEM projects, working in teams under the mentorship of educators. The program required students to dedicate eight hours per day, five days per week, culminating in presentations evaluated by peers and faculty members.

By the end of both programs, informal feedback was collected through paintings (K-8) and open essays (grades 9-12). The findings demonstrated significant positive outcomes: in Croatia, 500 learners participated in the initiative within two years, while in Puerto Rico, the 15-year program impacted over 4,550 students from 225 schools. Moreover, 100% of participants transitioned to college, with 85% pursuing STEM-C-related fields.

Findings and Recommendations

The study concluded that early exposure to computer science significantly benefits students, even when introduced through drag-and-drop programming techniques [8]. However, researchers recommended a more continuous approach, advocating for an integrated K-12 curriculum rather than separating short- and long-term initiatives.

While the study yielded promising results, some methodological details were unclear. For example, it did not specify which coding games or activities were used for K-8 students, possibly due to annual curriculum modifications. Future research should provide a more detailed methodology to strengthen the study's replicability.

Overall, the findings highlight the importance of early computer science education and the need for structured, long-term initiatives that support students throughout their academic journey. A well-supported primary education curriculum can help develop a generation of learners who are not only STEM-conscious but also proficient in coding, logical reasoning, and algorithmic thinking.

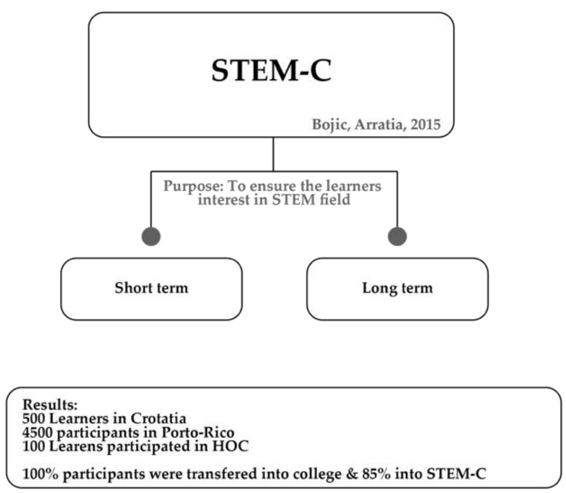

Figure 1: Literature Review Summary

METHODOLOGY

This study follows a quantitative research design and was conducted with 127 Grade 5 learners, aged 10–11 years, in a private school located in the capital city of Lebanon, Beirut. The school is situated in a densely populated area and has a relatively high number of students enrolled across all K-12 levels. The participants in this study, like most learners in Lebanon, receive instruction in scientific subjects in English. Consequently, the intervention, including the questionnaire, was conducted in English.

The school was selected as a convenient sample, as it agreed to implement the intervention, aligning with its vision. While middle school learners in this institution already receive coding instruction, the school saw this study as an opportunity to pilot coding education at the primary level. All sessions were conducted in person within the school premises.

Conceptual Framework

Successfully integrating coding into any classroom requires adjustments before and during implementation. One of the key pillars of such a change is understanding relevant learning theories. Additionally, differences in technology use and educational standards were addressed to facilitate smooth classroom implementation.

The frameworks guiding this study included the Technological Pedagogical Content Knowledge (TPACK) model and Project-Based Learning (PBL). These frameworks addressed the social and pedagogical aspects of implementation. Based on these insights, a tailored framework was developed to suit the Lebanese context. The study's significance lies in its focus on developing computational thinking skills, preparing learners for future careers, and assessing their abilities based on skills and personal engagement rather than rote memorization.

Theoretical Framework

A theoretical model was established to outline the study’s independent (IV) and dependent (DV) variables. This began with identifying the research problem and its objectives. The TPACK framework served as the primary guide for technology integration, emphasizing three core components:

- **Content Knowledge (CK):** Teachers' depth of knowledge in the subject matter.
- **Pedagogical Knowledge (PK):** Effective teaching strategies, classroom management, and learner engagement.
- **Technological Knowledge (TK):** Learners' ability to use digital tools effectively.

Data Collection Method

A questionnaire was used to collect quantitative data, which was later analyzed using SPSS. The primary goal was to assess learners’ perceptions of their critical thinking, problem-solving, coding abilities, and hands-on skills throughout the intervention. The questionnaire employed a four-level Likert scale, ranging from "Strongly Disagree" to "Strongly Agree," and was used as both a pre- and post-assessment tool.

The questionnaire was chosen for its efficiency in gathering large-scale data from multiple respondents simultaneously. Since there was limited research on coding and critical thinking at the primary education level, the questionnaire was designed to align with the study’s objectives, research questions, and the Lebanese curriculum while accommodating the learners’ cognitive levels.

The questionnaire measured critical thinking by evaluating reasoning skills and alignment between thought processes and actions. It comprised closed-ended questions grouped into four categories: Critical Thinking, Problem-Solving, Planning, and Technology. Closed-ended questions were preferred for their efficiency in data collection and analysis, as they provided clearer and more structured responses compared to open-ended questions.

To ensure clarity and appropriateness for the target audience, all questions were written in simple English, avoiding complex or emotionally charged wording. Positively phrased questions were used to enhance comprehension and prevent response bias. A four-level Likert scale was chosen to avoid neutral responses, ensuring clear insights into learners' perspectives. Research suggests that an asymmetric Likert scale compels respondents to take a stance rather than opting for a neutral position [12].

Questionnaire Validity and Reliability

To ensure validity, both face and content validity assessments were conducted. Content validity ensured that the questionnaire effectively measured the intended concepts, while face validity was achieved through expert review. A panel of domain experts reviewed the questionnaire to identify ambiguous or misleading questions and suggested refinements in wording and sequencing.

A pilot test was conducted with Grade 5 learners from a similar private school to evaluate the questionnaire's structure, language, completion time, and clarity. Minor modifications were made based on learners' feedback regarding unfamiliar words.

To test reliability, a Cronbach's Alpha test was performed to assess internal consistency. The results from the pilot test (N=16) were as follows:

Table 1 Cronbach Alpha Results for Questionnaire (Pilot)

Questionnaire	Pilot
Critical thinking	0.705
Problem solving	0.707
Planning	0.718
Technology	0.746

These values indicate a strong level of internal consistency, confirming the reliability of the questionnaire as a data collection instrument.

Project Rubric

In addition to the questionnaire, a project rubric was used as a quantitative tool to assess group performance and track progress over time. Initially inspired by the "Maryland STEM" rubric, it was adapted to align with the study's objectives and research questions. The rubric employed a four-level Likert scale (1–4), with 1 being the lowest and 4 representing excellence in measured criteria. The rubric assessed three primary categories: Skills, Technology, and Coding. It was designed to facilitate accurate and structured evaluation by teachers.

Project Rubric Validity and Reliability

The rubric was validated by a panel of five professors specializing in education, technology, science, and computer science. Their feedback ensured that the rubric authentically measured learners' abilities.

For reliability testing, two teachers used the rubric to assess four different student groups. The collected data was analyzed in SPSS, yielding the following results:

Table 2 Project Rubric Cronbach Alpha

Reliability Statistics		
Cronbach's Alpha	**Cronbach's Alpha Based on Standardized Items**	**N of Items**
.802	.795	13

Since the Cronbach's Alpha value exceeded 0.7, the rubric was deemed reliable. No items were removed as all questions contributed meaningfully to the assessment.

Intervention

The intervention took place from January to the first week of June, with weekly sessions. Learners were introduced to coding concepts, tools, and project workflows. Prior to the intervention, teachers administered the pre-questionnaire, explaining its purpose and reassuring learners that there were no right or wrong answers.

Throughout the intervention, students reflected on their learning experiences, identifying areas where they needed support and highlighting their achievements. The intervention provided a structured approach to introducing coding at the primary level, ensuring that learners gained both theoretical knowledge and practical skills.

Table 3 Implementation Sessions Distribution

Sessions Distribution	**Session/s detail**
Session 1	Pre-questionnaire + Introduction
Session 2	Sessions approaches and strategies
Session 3	Introduction to the tool.
Sessions 4 – 8	Project 1
Sessions 9 – 14	Project 2
Sessions 15 – 20	Project 3
Session 21	Post questionnaire + Wrap up

Ethical Consideration

To ensure that this study abide by the ethical consideration, a consent was collected from:

- The school to show their acceptance to implement the intervention
- The teachers that they accept to undergo training sessions that aims to showcase the aim and the approach to be used
- The learners parents to accept their child/children participation in this formal education that the school is planning to have in the following years.

FINDINGS AND ANALYSIS

The hypotheses for the research question for the study is the following:

- There is a significant difference in critical thinking disposition between the participants taught using coding relative to participants taught using traditional model.

The variables of this question are coding, critical thinking. To study the effect of coding and critical thinking, Crosstabulation, Chi-Square and Correlation tests were performed on pre and post-questionnaire of the experimental group. The Correlation test was performed to understand if there was a relationship between the variables. The same tests were performed on the post-questionnaire of the control group. The paired tests were performed to determine value of the mean difference of the two observances.

To study the effect of coding and critical thinking skills, a Chi-Square test was performed on the pre-questionnaire and post-questionnaire of the experimental group.

Pre-Questionnaire Experimental Group

Table 4 Critical thinking & technology: Crosstabulation pre-questionnaire

Critical Thinking and Technology Crosstabulation							
			Technology				**Total**
			Totally Disagree	**Disagree**	**Agree**	**Totally Agree**	
Critical thinking	Disagree	Count	1	1	4	4	10
		%	10.0%	10.0%	40.0%	40.0%	100.0%
	Agree	Count	0	1	13	11	25
		%	0.0%	4.0%	52.0%	44.0%	100.0%
	Totally Agree	Count	0	3	4	15	22
		%	0.0%	13.6%	18.2%	68.2%	100.0%
Total		Count	1	5	21	30	57
		%	1.8%	8.8%	36.8%	52.6%	100.0%

The results of (3x4) Crosstabulation between the critical thinking and technology in pre-questionnaire. The highest answers were for those who "Totally Agree" N=15 (68.2%), followed by "Agree" N=13 (52.0%), N=1 (10%) learner answered "Disagree" on both questions.

Table 5 Critical thinking & technology: Chi-Square Project Rubric

Chi-Square Tests						
	Value	**df**	**Asymptotic Significance (2-sided)**	**Exact Sig. (2-sided)**	**Exact Sig. (1-sided)**	**Point Probability**
Pearson Chi-Square	11.293[a]	6	.080	.060		
Likelihood Ratio	10.417	6	.108	.115		
Fisher's Exact Test	10.039			.068		
Linear-by-Linear Association	2.424[b]	1	.119	.131	.078	.031
N of Valid Cases	57					
a. 7 cells (58.3%) have expected count less than 5. The minimum expected count is .18. b. The standardized statistics is 1.557						

In the pre-questionnaire, the analysis showed 7 cells that had an expected count less than 5, so an exact significance text was selected for Pearson's Chi-Square. There was no statistical significance between critical thinking and technology $X^2(6, N= 57) = 11.29$ exact $p=0.06>0.05$.

Post-Questionnaire Experimental Group

The same tests (Crosstabulation and Chi-Square) were performed on the post-questionnaire.

Table 6 Critical thinking & technology: Crosstabulation post questionnaire

Critical thinking & Technology Crosstabulation

			Technology			Total
			Disagree	Agree	Totally Agree	
Critical Thinking	Disagree	Count	5	4	2	11
		% within Critical thinking	45.5%	36.4%	18.2%	100.0%
	Agree	Count	1	14	6	21
		% within Critical thinking	4.8%	66.7%	28.6%	100.0%
	Totally Agree	Count	1	10	15	26
		% within Critical thinking	3.8%	38.5%	57.7%	100.0%
Total		Count	7	28	23	58
		% within Critical thinking	12.1%	48.3%	39.7%	100.0%

The results of the square (3x3) Crosstabulation between the critical thinking and technology in post-questionnaire revealed that the highest answers were for those who “Totally Agree” (N=15), (57.7%), then “Agree” (N=14), (66.7%), followed by “Disagree” N=5 (45.5%).

Table 7 Critical thinking & technology: Chi-Square results post-questionnaire

Chi-Square Tests						
	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	18.920[a]	4	.001	.001		
Likelihood Ratio	15.533	4	.004	.006		
Fisher's Exact Test	14.351			.003		
Linear-by-Linear Association	11.127[b]	1	.001	.001	.001	.000
N of Valid Cases	58					
a. 4 cells (44.4%) have expected count less than 5. The minimum expected count is 1.33. b. The standardized statistics is 3.336						

In the post-questionnaire, the analysis showed 4 cells that had an expected count less than 5, so an exact significance text was selected for Pearson’s Chi-Square. There was statistical significance between critical thinking and technology X^2 (4, N=58) = 18.920 exact $P=0.01<0.05$; thus, phi value was analyzed.

Table 6 Critical thinking & technology: Phi Value post-questionnaire

Symmetric Measures						
		Value	Asymptotic Standardized Error[a]	Approximate T[b]	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.571			.001	.001
	Cramer's V	.404			.001	.001
Interval by Interval	Pearson's R	.442	.123	3.686	.001c	.001
Ordinal by Ordinal	Spearman Correlation	.416	.122	3.426	.001c	.001
N of Valid Cases		58				
a. Not assuming the null hypothesis.						
b. Using the asymptotic standard error assuming the null hypothesis.						
c. Based on normal approximation.						

Phi value=0.571 showed there was a strong relationship between critical thinking and coding.

The Spearman Correlation test r=0.416 showed a moderate Correlation between critical thinking and coding.

The results of the pre-questionnaire were not statistically significant between coding and critical thinking; however, after the intervention, the post-questionnaire showed statistically significant values; the coding had an impact on critical thinking.

Post-questionnaire Experimental Group

The same tests (Crosstabulation and Chi-Square) were performed on the post-questionnaire.

Table 7 Critical thinking & technology: Crosstabulation post questionnaire - Experimental Group

Critical Thinking* Technology Crosstabulation						
			Technology			Total
			Disagree	Agree	Totally Agree	
Critical thinking	Disagree	Count	5	4	2	11
		% within Critical thinking	45.5%	36.4%	18.2%	100.0%
	Agree	Count	1	14	6	21
		% within Critical thinking	4.8%	66.7%	28.6%	100.0%
	Totally Agree	Count	1	10	15	26
		% within Critical thinking	3.8%	38.5%	57.7%	100.0%
Total		Count	7	28	23	58
		% within Critical thinking	12.1%	48.3%	39.7%	100.0%

The results of the square (3x3) Crosstabulation between the critical thinking and technology in post-questionnaire revealed that the highest answers were for those who “Totally Agree” (N=15), (57.7%), then “Agree” (N=14), (66.7%), followed by “Disagree” N=5 (45.5%).

Table 8 Critical thinking & technology: Chi-Square results post-questionnaire

Chi-Square Tests						
	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	18.920[a]	4	.001	.001		
Likelihood Ratio	15.533	4	.004	.006		
Fisher's Exact Test	14.351			.003		
Linear-by-Linear Association	11.127[b]	1	.001	.001	.001	.000
N of Valid Cases	58					
a. 4 cells (44.4%) have expected count less than 5. The minimum expected count is 1.33.						
b. The standardized statistic is 3.336.						

In the post-questionnaire, the analysis showed 4 cells that had an expected count less than 5, so an exact significance text was selected for Pearson’s Chi-Square. There was statistical significance between critical thinking and technology X^2 (4, N=58) = 18.920 exact P=0.01<0.05; thus, phi value was analyzed.

Table 9 Critical thinking & technology: Phi Value post-questionnaire

Symmetric Measures

		Value	Asymptotic Standardized Error[a]	Approximate T[b]	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.571			.001	.001
	Cramer's V	.404			.001	.001
Interval by Interval	Pearson's R	.442	.123	3.686	.001c	.001
Ordinal by Ordinal	Spearman Correlation	.416	.122	3.426	.001c	.001
N of Valid Cases		58				
a. Not assuming the null hypothesis.						
b. Using the asymptotic standard error assuming the null hypothesis.						
c. Based on normal approximation.						

Phi value=0.571 showed there was a strong relationship between critical thinking and coding. The Spearman Correlation test r=0.416 showed a moderate Correlation between critical thinking and coding.

The results of the pre-questionnaire were not statistically significant between coding and critical thinking; however, after the intervention, the post-questionnaire showed statistically significant values; the coding had an impact on critical thinking.

Post-Questionnaire Control Group

The same tests (Crosstabulation and Chi-Square) were performed on the post-questionnaire control group.

Table 10 Critical thinking & Technology: Crosstabulation post-questionnaire - Control Group

Critical thinking & Technology Crosstabulation						
			Technology			Total
			Disagree	Agree	Totally Agree	
Critical thinking	Disagree	Count	5	4	2	11
		% within Critical thinking	45.5%	36.4%	18.2%	100.0%
	Agree	Count	1	14	6	21
		% within Critical thinking	4.8%	66.7%	28.6%	100.0%
	Totally Agree	Count	1	10	15	26
		% within Critical thinking	3.8%	38.5%	57.7%	100.0%
Total		Count	7	28	23	58
		% within Critical thinking	12.1%	48.3%	39.7%	100.0%

15 Learners answered with “Totally Agree” (57.7%) on both questions followed by (N=14), (66.7%) who answered with “Agree.” Only (N=5), (45.5%) answered with “Disagree.”

Table 11 Critical thinking & Technology: Chi square post-questionnaire - Control Group

Chi-Square Tests						
	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	7.557[a]	4	.109	.111		
Likelihood Ratio	9.075	4	.059	.089		
Fisher's Exact Test	6.088			.170		

Linear-by-Linear Association	.011[b]	1	.916	1.000	.526	.132
N of Valid Cases	29					
a. 8 cells (88.9%) have expected count less than 5. The minimum expected count is 1.10.						
b. The standardized statistic is -.106.						

In the post-questionnaire of the control group, the analysis showed 8 cells that had an expected count less than 5, so an exact significance text was selected for Pearson's Chi-Square. There was no statistical significance between critical thinking and technology X^2 (4, N=29)=7.557 exact P=0.111>0.05.

Comparing the results of the post-questionnaire of the control and the experimental group revealed that the results showed a statistical significance in the experimental group while they were not statistically significant in the post-control group.

A Paired Sample on Technology Experimental Group

A paired sample was done to examine the technology effectively in the pre and post-questionnaire of the experimental group.

Table 12 Technology: Paired sample statistics

Paired Samples Statistics					
		Mean	**N**	**Std. Deviation**	**Std. Error Mean**
Pair 1	Technology Pre	3.3860	57	.72591	.09615
	Technology Post	3.2632	57	.66886	.08859

A paired sample T-test was done on the critical thinking for the experimental group. The mean in pre and post-questionnaire decreased; $mean_{pre}$-$mean_{post}$ =0.12281.

Table 13 Technology: Paired sample T-test

Paired Samples Test									
		Paired Differences					**t**	**df**	**Sig. (2-tailed)**
		Mean	**Std. Deviation**	**Std. Error Mean**	**95% Confidence Interval of the Difference**				
					Lower	**Upper**			
Pair 1	Technology Pre Technology Post	.12281	.88782	.11759	-.11276	.35838	1.044	56	.301

The mean difference was 0.75. A paired T-test result showed that the difference between conditions was not significance (t=1.044, df=56, P=0.301>0.05).

A Paired Sample on Critical Thinking Experimental Group

A paired sample test was performed on critical thinking for the experimental group.

Paired Samples Statistics:

Table 14 Critical thinking: Paired Sample Statistics

	Mean	**N**	**Std. Deviation**	**Std. Error Mean**

Pair 1	Critical thinking Pre	15.7931	58	2.24592	.29490
	Critical thinking Post	15.6552	58	2.26763	.29775

A paired sample T-test was done on the critical thinking for the experimental group. The mean in pre and post-questionnaire decreased; $mean_{pre}$-$mean_{post}$ =15.7241-15.6552=0.37.

Table 15 Critical thinking: Paired sample test

Paired Samples Test									
		Paired Differences					**t**	**df**	**Sig. (2-tailed)**
		Mean	**Std. Deviation**	**Std. Error Mean**	**95% Confidence Interval of the Difference**				
					Lower	**Upper**			
Pair 1	Critical thinking Pre-Critical thinking Post	.13793	2.67180	.35083	-.56458	.84045	.393	57	.696

Paired T-test results showed that the difference between conditions was not significant (t=0.393, df=57, P=0.696>0.05).

Independent T-test:

An independent T-test was performed on the control and experimental groups to check the critical thinking level.

Table 16 Critical thinking: Group statistics - Control & Experimental Group

Group Statistics					
	Exp Or Control	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
Critical thinking	control	56	15.6429	2.56145	.34229
	experimental	59	15.6271	2.25831	.29401

The mean was the same in both the control and experimental groups, $mean_{control}$= 15.6429 and $mean_{experimental}$ = 15.6271.

Table 17 Critical thinking: Independent sample test

Independent Samples Test										
		Levene's Test for Equality of Variances		**T-test for Equality of Means**						
		F	**Sig.**	**t**	**df**	**Sig. (2-tailed)**	**Mean Difference**	**Std. Error Difference**	**95% Confidence Interval of the Difference**	
									Lower	**Upper**
Critical Thinking	Equal variances assumed	.357	.551	.035	113	.972	.01574	.44974	-.87527	.90675
	Equal variances not assumed			.035	109.548	.972	.01574	.45122	-.87852	.91000

The independent T-test showed that the difference between the conditions was not statistically significant, P=0.972< 0.05 (t=-0.035, df=113, P=0.972).

Project Rubric

Critical Thinking and Coding:

The following section discusses the coding effect of the project rubric on critical thinking skill.

Table 18 critical thinking & coding Crosstabulation Project rubric

Skills_Critical thinking * Coding Crosstabulation						
			coding			**Total**
			Somewhat Relevant	**Relevant**	**Very Relevant**	
Skills_Critical Thinkinng	Relevant	Count	1	15	11	27
		% of Total	1.9%	28.3%	20.8%	50.9%
	Very Relevant	Count	0	13	13	26
		% of Total	0.0%	24.5%	24.5%	49.1%
Total		Count	1	28	24	53
		% of Total	1.9%	52.8%	45.3%	100.0%

The results of (2x3) Crosstabulation between the critical thinking and coding project rubric. The highest answers were for those who answered by “Relevant” (N=11), (20.8%), followed by “Very Relevant” (N=13), (24.5%).

Table 19 Critical thinking & coding: Chi square Project rubric

Chi-Square Tests						
	Value	**df**	**Asymptotic Significance (2-sided)**	**Exact Sig. (2-sided)**	**Exact Sig. (1-sided)**	**Point Probability**
Pearson Chi-Square	1.291[a]	2	.524	.682		
Likelihood Ratio	1.677	2	.432	.682		
Fisher's Exact Test	1.244			.682		
Linear-by-Linear Association	.771[b]	1	.380	.446	.266	.139
N of Valid Cases	53					
a. 2 cells (33.3%) have expected count less than 5. The minimum expected count is .49.						
b. The standardized statistic is .878.						

In the project rubric, the analysis showed that 2 cells had an expected count less than 5, so an exact significance test was selected for Pearson's Chi-Square. There was no statistical significance between critical thinking and coding $X^2(2, N=53) = 1.291$ exact P=0.682>0.05.

Conclusion

Several tests were performed to better understand the connection that existed between coding and critical thinking skills. The study suggested that critical thinking was significantly different if compared with the control group when taught in hands on approach rather than the traditional teaching approach.

Qualitative

The learners' interview, revealed that they were using terminologies that were used to state the aim of the study. The learners believed they could solve a problem after understanding the steps to its solution "I can solve everything." They, also, tried experimenting and exploring to find a solution; this tinkering technique allowed them to link things together and gave them a chance to construct their understanding based on that knowledge and experience [16]. If that were the only benefit from the study, the study would be successful. Moreover, the learners coded different tasks that were not provided and part of the study to do whatever they wanted. For example, when given the time to take the project a step further, the learners decided to modify the original code.

Quantitative

Coding and Critical Thinking:

Comparing the pre-questionnaire of the experimental group with the post-questionnaire revealed a statistical significance. The pre-questionnaire results were not significant, while the post-questionnaire were significant P=0.47. The Phi Value Phi=0.573 showed a strong relationship between coding and critical thinking.

As coding required critical thinking to find a functioning algorithm, it might be the reason why the results were better in the experimental group. Since the coding was the glue that held the project together, it was the primary key to making the project work and giving the instruction for the microcontroller.

Paired T-test:

Coding: Comparing the of pre and post results of the coding section, results showed there was no statistical significance between the paired groups.

Critical thinking: Comparing the pre and post results of the critical thinking, results showed there was no statistical significance between the paired group.

Independent T-test:

When comparing the results of the critical thinking in the control group and the experimental group, it was revealed that the results showed insignificant results.

Project Rubric

Coding and Critical Thinking:

The results of coding and critical thinking in the project rubric were not significant. During the conference, [17] asserted the need for STEM skills to find solutions for the problems we were facing in Lebanon. For that to be reached, a new teaching approach was needed to shift from consumers [18] to producers. For this, the study was based on tinkering, trying and experimenting [19].

All T-tests were not significant, but Chi-Square showed a strong relationship between coding and critical thinking. Another point was that coding required higher order thinking skills, which fell under constructivism [20], yet many enjoyed coding and were much interested in it [8], while some argued it should be taught at a young age to develop other skills [2] as the study revealed. Moreover, teaching coding was not easy as it required basic reasoning skills [22]. On top of that, coding skill was mandatory for learners to advance in their future jobs [23]. However, the learners' results in the post questionnaire coding section showed a decreased average in the answers, which could be referred to their different understanding of what coding indicated and what its real potential was; something the learners did not know before experimenting and having a hands-on class.

CONCLUSION

The integration of coding into the learning process significantly fostered critical thinking skills among learners, though this development required time and gradual adaptation. The study's population lacked the opportunity to engage in alternative learning environments where they could experiment and explore independently. As learners began to feel more confident, they started to evaluate and modify their plans based on their personal experiences, a key aspect of critical thinking. Initially, learners felt more comfortable relying on textbooks than engaging in self-directed exploration. However, a marked difference in critical thinking emerged between the control and experimental groups, highlighting the benefits of an experimental learning approach. The combination of hands-on activities, planning sheets, and collaborative discussion sessions created a safe environment for learners to experiment. With time, the teacher's role evolved from simply adhering to a schedule to actively supporting each learner's development, offering guidance and resources tailored to individual and team needs. While progress was evident, greater success might have been achieved if the integration of coding was spread across multiple sessions throughout the day, rather than confined to one session per week. A unified definition of critical skills across the school would also help students understand the interconnectedness of concepts in different contexts. A well-defined school vision is essential to shaping a positive school culture that influences educational outcomes. For example, if key concepts were reinforced by different teachers across various sessions, students would better understand the real-world relevance of what they learned, connecting subject matter to everyday problems.

Limitations

The findings of this study were subject to several limitations, which are outlined below:

1. **Extraneous Variables**: To control for extraneous variables, the study was conducted in a single school. While the sample size (N=127) was adequate, the results reflect the specific learners and school environment, and may not be generalizable to other contexts. Replicating this study across different schools would provide more comprehensive insights into the broader applicability of the findings.
2. **Teacher Perceptions of Critical Thinking**: The variation in teachers' understanding and definitions of critical thinking posed a limitation. While diverse perspectives on critical thinking can enrich educational practices when shared within a teacher community, inconsistent interpretations can hinder the systematic development of these skills in students. A common, unified approach to teaching critical thinking would enhance the effectiveness of instruction.

Recommendations

The following recommendations are proposed at two levels: classroom transformation and future research.

1. **Classroom Transformations**: Despite the availability of modern teaching methods, traditional approaches still dominate classroom practices. It is recommended to further

integrate coding and technology into subject-specific lessons, as this approach has shown clear engagement benefits. Incorporating computational thinking into various subjects will help students develop essential problem-solving skills. Additionally, greater emphasis on coding at the primary education level is recommended due to its broad impact on skill development.

2. **Future Studies**: To deepen our understanding, it is recommended to replicate this study across both private and public schools and compare the outcomes. This will provide a broader perspective on the effects of coding on critical thinking in diverse educational settings.

Closure

This study makes a significant contribution to the educational literature in several ways:

1. **Limited Scope of Previous Research**: While studies on coding and its effects on learners have been limited within the Lebanese context, this study provides valuable insights into the local educational landscape by using Lebanese textbooks and maps as part of the classroom projects.
2. **Contextual Relevance**: The findings of this research offer a deeper understanding of the Lebanese context, making it possible to implement coding in a manner that aligns with local needs and educational structures.
3. **Development of Learning Skills**: The primary focus of the study was to enhance learning skills that will help students thrive in the future. By emphasizing skill-based learning, the study serves as an initial step toward creating more effective, skill-oriented classrooms.
4. **Framework for Coding Implementation**: Various frameworks for coding integration exist; this study presents a conceptual and pedagogical framework that guided the research and can be applied to similar classroom settings with a focus on coding and skill development.

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