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Effect of Unplugged Activities on Computational Thinking Skills of Grade 5 Students in Mathematics

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ABSTRACT
This study examined the effect of unplugged activities on the computational thinking skills of Grade 5 students in mathematics in District Faisalabad, Pakistan. The study was based on the view that computational thinking can be developed through regular mathematics teaching even in schools where digital resources are limited. Four components of computational thinking were considered: decomposition, pattern recognition, abstraction, and algorithmic thinking. A quasi-experimental pre-test–post-test control group design was used. The sample consisted of 60 Grade 5 students selected from a public school, with 30 students in the experimental group and 30 in the control group. The experimental group was taught through researcher-developed unplugged activities integrated with Grade 5 mathematics content, while the control group received the usual teaching method. The intervention lasted for eight weeks, with five sessions per week. Data were collected through a researcher-developed computational thinking test. The pilot version of the instrument showed good reliability ($\alpha = .847$), and the final 20-item form also showed satisfactory internal consistency ($\alpha = .827$). Data were analyzed through descriptive statistics, independent-samples t-test, analysis of covariance, and comparative domain-wise analysis. The findings showed that unplugged activities had a statistically significant positive effect on students' overall computational thinking skills. After adjustment for pre-test differences, the experimental group obtained a higher post-test mean than the control group in overall computational thinking as well as in all four domains. The strongest improvement was found in algorithmic thinking, followed by decomposition, abstraction, and pattern recognition. The study concludes that unplugged activities provide a practical and effective way to develop computational thinking in primary mathematics, especially in low-resource public-school settings. The findings support the integration of computational thinking into mathematics teaching through structured, activity-based classroom practices.

Keywords: *Computational Thinking, Unplugged Activities, Grade 5 Mathematics, Primary Education, Quasi-experimental Design*

Introduction
In the contemporary world of education, schools are supposed to do more than impart children with facts to memorize and repeat the usual processes. Computational thinking has emerged as a concept within this broader education change. Wing (2006) created

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significant emphasis around the idea when he claimed that computer scientists are not the only users of computational thinking. She defined it as a method of solving problems by organizing information, simplifying it and coming up with practical solutions. In school learning, this means that computational thinking is useful wherever students are required to think logically, deal with unfamiliar situations, and move through a task in a logical order. For this reason, researchers take computational thinking as part of twenty-first century skill rather than as a limited technical skill.

Mathematics provides a strong context for the development of computational thinking. In mathematics, students break a problem into parts, notice regularities, ignore unnecessary information, and apply or design a sequence of steps. These actions are closely related to the components of computational thinking that are found in literature. Weintrop et al. (2016) argued that computational thinking can be meaningfully framed for mathematics and science classrooms. It is not restricted to programming lessons only. In a similar way, Rich et al. (2019) observed that integrating computational thinking into school subjects can extend students' access to these forms of thinking because learners face them in regular classroom activities instead of specialized computer courses only.

The current research is carried out in this educational requirement. It explores how the unplugged activities influence the computational thinking of Grade 5 students in mathematics in District Faisalabad, Pakistan. The paper concentrates on four key elements of computational thinking: decomposition, pattern recognition, abstraction, and algorithmic thinking. Through their analysis in the context of primary mathematics, the research aims to present educationally practical, contextually based, and directly related evidence with realities of the teaching of mathematics in the public schools.

The evidence for unplugged approaches has grown stronger in recent years. Chen et al. (2023) reported a generally large positive effect of unplugged activities on students' computational thinking skills across K-12 settings through a systematic literature review and meta-analysis. Li et al. (2022) also found that both unplugged activities and programming or plugged exercises can support computational thinking, while observing that unplugged approaches are especially meaningful in interdisciplinary and primary-level contexts. These findings are particularly important for settings where access to digital resources is uneven because they show that computational thinking can still be developed through carefully designed classroom activities.

Computational thinking is a fast-growing educational competency that is becoming more and more significant, but whose development in classrooms is unequal and not always properly comprehended. The literature indicates a general consensus that computational thinking aids structured problem solving, in particular, by decomposition, pattern recognition, abstraction, and algorithmic thinking (Shute et al., 2017; Wing, 2006). Nevertheless, the possibilities to nurture these skills in a typical school environment, especially at the primary level, are scarce, with limited access to digital resources.

Methodology

This study used a quasi-experimental pretest posttest control group design to examine the effect of unplugged activities on the computational thinking skills of Grade 5 students in mathematics. The design was chosen as the study was carried out in an actual school environment where students were already put in existing sections. Random assignment may not be feasible in this case since the schools are not typically willing to reassign students just to conduct a study. This is why quasi-experimental designs are commonly

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employed by educational researchers who are interested in researching the impact of an instructional treatment in a natural classroom setting (Campbell and Stanley, 1963; Creswell and Creswell, 2018; Shadish et al., 2002).

The target population of the study consisted of all Grade 5 students enrolled in public elementary schools in District Faisalabad. In educational research, the population refers to the full group to which the researcher wishes to relate the findings (Creswell & Creswell, 2018). Grade 5 was selected because the study focused on primary-level mathematics and because students at this stage are developmentally able to engage with basic forms of decomposition, pattern recognition, abstraction, and algorithmic thinking when tasks are presented in an age-appropriate way.

Because it was not possible to approach every public elementary school in the district, the researcher worked with an accessible population. The accessible population was drawn from one public school in District Faisalabad that granted permission for the study and had two intact Grade 5 sections available for comparison. The selected school was suitable for the study because it provided the required administrative support, regular classroom access, and comparable conditions for both groups.

The sample consisted of 60 students from the two Grade 5 sections of the selected school. Each section included 30 students. One section was assigned as the experimental group and the other as the control group. Students were not randomly assigned to groups since the sections existed previously. This design is typical of quasi-experimental studies in schools, where intact classes are employed due to practical and ethical considerations (Fraenkel et al., 2019; Shadish et al., 2002).

A non-probability sampling technique was employed in the study. The convenience sampling was applied at the school level since the school chosen was available to the researcher and was willing to take part in the research. In educational studies, convenience sampling is common when the accessibility relies on school permission, schedule availability, and administrative assistance (Cohen et al., 2018; Fraenkel et al., 2019). Despite the fact that this method reduces the possibilities of generalizing the results, it is commonly used in intervention studies that are held in real school settings.

The main instrument of the study was a researcher-developed Computational Thinking Test prepared for Grade 5 students in mathematics. The purpose of the instrument was to measure students' computational thinking before and after the intervention. Since no standardized test suited to the local context and the exact focus of the study was available, the researcher developed the instrument in light of the conceptual framework discussed in Chapter 2. The test was aligned with four domains of computational thinking: decomposition, pattern recognition, abstraction, and algorithmic thinking. These domains were selected because they are widely discussed in the literature and because they can be meaningfully embedded in primary mathematics content (Shute et al., 2017; Weintrop et al., 2016).

The instrument was designed as a short-response, performance-based assessment rather than a simple objective test. This format was selected because computational thinking is not limited to choosing correct options. It also involves showing a process, organizing steps, identifying patterns, and separating relevant from irrelevant information. A short-response format therefore allowed students to display their reasoning more clearly. In studies of higher-order thinking, performance-based tasks are often more suitable than recognition-based items because they capture how students approach a problem, not only whether they select the right answer (Shute et al., 2017).

Reliability is a measure of the consistency of a measuring tool. A sound instrument generates consistent and internally consistent scores when applied to a similar group of respondents under comparable circumstances (Creswell and Creswell, 2018; Field, 2018). Since the current instrument was created and optimized by the researcher, internal consistency reliability was tested with the help of Cronbachs alpha in SPSS.
The final 20-item version of the test was administered in the main study to 60 students. The Cronbach alpha value of the final instrument was .827 and on Standardized Items was .832. These values indicate that the short form of the test retained good internal consistency. Alpha values of above.80 are mostly satisfactory in research in classroom-based educationalstudies (Field, 2018). The latter tool was thus deemed appropriate to be used in the primary analysis.

The data collection procedure was conducted in a systematic order within eight weeks in the sampled school of the District Faisalabad. The school administration was asked to give permission before the study commenced. The research intent, type of intervention, and the anticipated time of classroom participation were communicated to the concerned school authorities to ensure that the study was conducted without problems throughout the normal school time.

Upon approval, the two Grade 5 sections were identified and assigned to experimental and control groups. The pre-test was done under similar classroom conditions first by both groups. The instructions to the students were presented in plain language and time was given to the students to go through all the items on their own. Baseline performance was determined with the pre-test scores which were later taken as covariate in ANCOVA.

The experimental group started the intervention after the pre-test. The unplugged activities were incorporated in mathematics lessons and were carried out during eight weeks with five sessions in one week with an average of thirty-five minutes. The activities were modeled on the four areas of computational thinking and were connected to Grade 5 mathematics information. The control group proceeded with normal instruction in the same time frame. This arrangement made it possible to compare the learning outcomes of the two groups after similar exposure to classroom teaching time.

At the end of the intervention period, the post-test parallel form was administered to both groups under conditions similar to those used for the pre-test. All answer sheets were collected and marked using the same rubric. The scored data were then coded and entered into SPSS for statistical analysis. Care was taken to record scores accurately so that both total and domain-wise analyses could be conducted in Chapter 4.

Data Analysis
The data were marked and then loaded into SPSS Version 27 to be analyzed. The initial process was screening of data. The scholar checked the data of missing values, coding and abnormal entries. The entire dataset was preserved to analyze the 60 cases due to the completeness of the dataset. After screening the data, descriptive and inferential statistics were used as per objective of the study.

Table 1: *Demographic Characteristics of the Participants (N = 60)*

Variable	*Category*	*f*	*%*
Gender	Female	17	28.3
	Male	43	71.7
Teaching Group	Experimental	30	50.0

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Variable	*Category*	*f*	*%*
	Control	30	50.0

The demographic features of the participants in the study are presented in table 1. Out of the total 60 students, 17 (28.3%) were female and 43 (71.7%) were male. The subjects were balanced equally between the two teaching groups (30 students, 50.0% in the experimental group and 30 students 50.0% in the control group).

Table 2: *Descriptive Statistics of Pre-test and Post-test Scores for Computational Thinking and its Domains*

Variable	*N*	Minimum	Maximum	*M*	*SD*
Decomposition Pre-test	60	0	8	3.42	1.934
Pattern Recognition Pre-test	60	0	10	3.23	2.801
Abstraction Pre-test	60	0	9	3.25	2.176
Algorithmic Thinking Pre-test	60	0	8	3.37	1.931
Total CT Pre-test	60	1	30	13.27	6.340
Decomposition Post-test	60	0	9	4.40	2.901
Pattern Recognition Post-test	60	0	10	4.83	3.561
Abstraction Post-test	60	0	10	4.28	3.076
Algorithmic Thinking Post-test	60	0	10	5.40	2.800
Total CT Post-test	60	0	38	18.92	11.201

The descriptive statistics of the pre-test and post-test scores of students in overall computational thinking and the four domains are provided in table 2. The results show that the mean score for total computational thinking increased from 13.27 at the pre-test stage to 18.92 at the post-test stage. This improvement shows that students, in general, did better on the post-test compared to the pre-test. Equally, all four areas of computational thinking had positive gains. The average scores of decompositions were raised by 0.42 to 4.40, pattern recognition by 3.23 to 4.83, abstraction by 3.25 to 4.28, and algorithmic thinking by 3.37 to 5.40. These descriptive results imply the general positive change in the performance of computational thinking of students during the study.

Table 3: *Independent-Samples t-Test for Pre-test Equivalence on Total Computational Thinking*

Variable	Group	*N*	*M*	*SD*	*t*	*df*	*p*
Total CT Pre-test	Experimental	30	15.03	6.734	2.230	58	.030
	Control	30	11.50	5.476			

The findings of the independent-samples t-test performed to test pre-test equivalence between the experimental and the control groups in terms of total computational thinking scores are presented in Table 3. The findings show that the mean pre-test score of the experimental group (M = 15.03, SD = 6.73) was greater than that of the control group (M = 11.50, SD = 5.48). The two groups were significantly different, t (58) = 2.23, p =.03. This implies that the two groups were not completely comparable when the study started.

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Table 4 *Descriptive Statistics for Overall Computational Thinking Scores*

Measure	*Group*	*N*	*M*	*SD*
Total CT Pre-test	Experimental	30	15.03	6.734
	Control	30	11.50	5.476
Total CT Post-test (Unadjusted)	Experimental	30	26.83	9.274
	Control	30	11.00	6.292
Total CT Pre-test (Overall)	Total	60	13.27	6.340
Total CT Post-test (Overall)	Total	60	18.92	11.201

Table 4 indicates that the experimental group had slightly higher mean pre-test score than the control group. It also indicates that the experimental group got a significantly high unadjusted post-test mean compared to the control group. Though already these descriptive differences indicate the positive impact of unplugged activities, the inferential analysis was needed to find out whether the difference was still significant after statistical control of pre-test performance.

Table 5: *Tests of Between-Subjects Effects for Overall Computational Thinking (ANCOVA Model)*

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	5417.479	2	2708.740	77.778	.000	.732
Intercept	318.173	1	318.173	9.136	.004	.138
Group * CT_Pre	5417.479	2	2708.740	77.778	.000	.732
Error	1985.104	57	34.826			
Total	28873.000	60				
Corrected Total	7402.583	59				

Note. $R^2 = .732$; *Adjusted* $R^2 = .722$

The general ANCOVA model of the total post-test scores of computational thinking is shown in Table 5. The adjusted model was significant which means the model fitted explained a significant percentage of variation in post-test computational thinking. The value of R 2 is.732 indicating a good fit to the model. In the current research, this finding is a good indication that the post-test computational thinking performance was significantly related to the adjusted model that incorporated teaching-group membership and pre-test control.

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Table 6 *Comparison of Adjusted Mean Scores across the Four Computational Thinking Domains*

Domain	Experimental Adjusted Mean	Control Adjusted Mean	Mean Difference
Decomposition	6.115	2.685	3.430
Pattern Recognition	6.325	3.341	2.984
Abstraction	6.021	2.545	3.476
Algorithmic Thinking	7.099	3.701	3.397

Table 6 indicates that the experimental group had better adjusted post-test means compared to the control group in the four areas of computational thinking. This validates the fact that unplugged activities positively influenced all components. It is also indicated in the table that the adjusted post-test level of algorithmic thinking was highest in the experimental group and pattern recognition had the least adjusted mean difference between the groups. On the whole, the adjusted mean comparison shows that the intervention positively impacted all domains, but the extent of the benefit was different among the components.

Discussion

The findings of the study show that unplugged activities can significantly improve the computational thinking skills of Grade 5 students in mathematics. The overall result supports the broader argument that computational thinking does not depend on digital tools alone. Instead, it can be developed through carefully planned classroom activities that require students to reason, organize information, and solve problems in a structured way.

The present findings are in line with studies and reviews that have reported positive effects of unplugged learning on computational thinking. Chen et al. (2023) reported a generally positive and substantial effect of unplugged activities across K-12 settings, and the present study supports that conclusion in a Pakistani public-school mathematics classroom. The findings also support Li et al. (2022), who noted that unplugged approaches can be meaningful in interdisciplinary and primary-level contexts. In the same way, the positive results of this study are consistent with Hu and Wang (2024), who found that unplugged activities in elementary mathematics improved students' computational thinking.

The results also support the view that mathematics is an authentic setting for computational thinking. This is consistent with Weintrop et al. (2016), who argued that computational thinking can be framed productively for mathematics and science classrooms, and with work that highlights the compatibility of computational thinking with mathematical reasoning at the primary level. In the present study, students did not engage in coding. Yet they still showed meaningful improvement in structured thinking through ordinary mathematics content. This is important because it shows that computational thinking can be integrated into subject teaching rather than being treated as an isolated technical topic.

The domain-wise findings add another important point. All four domains improved significantly, but the strongest improvement was found in algorithmic thinking. This may be because the intervention included many classroom tasks that required students to arrange steps, follow procedures, and solve problems in an orderly

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way. Since Grade 5 mathematics already includes many procedural tasks, algorithmic thinking may have been more directly activated than the other domains. At the same time, the significant gains in decomposition, abstraction, and pattern recognition show that the intervention had broad rather than narrow cognitive value.

The study also extends earlier literature by providing evidence from a context that is less represented in computational thinking research. Much prior work has been carried out in technology-rich settings or outside Pakistani public schools. The present findings show that meaningful improvement is possible even in a low-resource mathematics classroom. This gives the study practical value for schools that may not have regular access to computers, internet, or specialized software.

Conclusions

Based on the results of the research, the conclusion is that unplugged activities are a viable teaching method of acquiring computational thinking skills in Grade 5 mathematics students. The scores were always in the favour of the experimental group in the general computational thinking and in all the four domain-specific comparisons. This demonstrates that mathematical instruction can be significantly used to build computational thinking provided that lessons are designed to focus on analysis, participation, structure and reasoning.

Another conclusion of the study is that the most impacted area of the intervention was algorithmic thinking. All four domains had significant improvements, but algorithmic thinking demonstrated the most adjusted post-test performance and the greatest effect size. This indicates that procedural reasoning is particularly enhanced by means of structured and step-by-step classroom work with upper-primary students. This area could be particularly sensitive to unplugged teaching since Grade 5 mathematics already involves a lot of orderly procedure.

Recommendations

1. It is suggested that the primary mathematics teachers in their classes should adopt unplugged and activity-based methods to build in the students the ability to think in a computational manner.
2. It is also advisable that school heads and administrators assist teachers to adopt such
   practices. Since unplugged instruction is not reliant on technology to a large extent, simple materials like chart paper, flash cards, worksheets, counters, paper shapes and group-task materials can be encouraged by schools.
3. In the case of curriculum developers, it is suggested that computational thinking should be better incorporated into primary mathematics curricula and textbooks.
4. In the case of teacher education and professional development programs, training on computational thinking is recommended to be part of pre-service and in-service preparation.

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