Social Sciences & Humanity Research Review
ISSN 3007-3170(O), ISSN :3007-3162(P)
Volume 3 issue 1,pp. 541-557
January-March 2025

Received: 05 January 2025 ,Accepted: 25 February 2025
DOI: https://doi.org/10.33282/jssr.vx2i4.31

DEVELOPMENT OF COMPUTATIONAL THINKING THROUGH THE SCRATCH PROGRAMMING SOFTWARE IN ELEMENTARY SCHOOL STUDENTS

[1]Mujahid Ahmad, Dr. Bushra Naoreen

1. PhD Scholar, Department of Education, GC University Faisalabad
   nhss.rabwah@gmail.com
2. Associate Professor, Department of Education, GC University Faisalabad
   bushranaoreen@gcuf.edu.pk

Abstract

Computational thinking is a newly emerged skill which can be used even without using computer hardware for problem solving. It has been listed in the skills of 21st century skills. The STEM subjects are the subjects when are taught in classroom needs hands on activities either through programming or other tools to promote higher order thinking in students. There are only a few studies which introduced programming environments for development of computational thinking skills either through a specific subject or in general so research in this field was needed to be initiated to probe out the potential benefits of programming environments in learning process. In Pakistan perspective computational thinking is a totally new field which was needed to be studied. The study used user friendly open source software named as Scratch software to develop computational thinking skills of elementary school students. The study was being the experimental in nature and true experimental research design used. The four groups were used as sample for the study in which two groups are of male students and the other two of female students. Self-developed modules through scratch software were used as intervention to develop computational thinking. The results indicated that intervention of Scratch software to develop computational thinking has significant impact. It is also noted that academic performance significantly improved with the induction of Scratch software in the classroom instruction. The study concluded that gender has no impacts on results as long as development of Computational thinking and academic performance.

Keywords: Computational thinking, development, Scratch software

Social Sciences & Humanity Research Review
ISSN 3007-3170(O), ISSN :3007-3162(P)
Volume 3 issue 1,pp. 541-557
January-March 2025

1. INTRODUCTION

Computational thinking is a process of thinking logically to solve a problem, it can be developed by training about the steps of problem solving, as decomposition of the problem, recognizing patterns, abstraction and then developing algorithms to reach conclusions (Grover & Pea, 2013). Although some concepts of computational thinking was evolved in the last century but it was believed for a time that it was only for computer and computer related subjects and problems. Wing (2006) was first who not only defined many aspects of computational thinking but also explained that it was not limited to computer but can also be implied in other disciplines of life to solve problems. Research also suggested that computational thinking can be integrated with our daily life problems. It is also believed that CT is a higher order thinking skill which can be developed by students either they are of junior school or higher education (Shute *et al*, 2017).

Computational thinking allows us to follow the process same as of computer to solve a problem without using hardware in everyday life(Grover & Pea, 2013) as wing (2008) clarified that CT is an abstraction or logical thinking to solve the problems better than computers as computer solutions were programmed but human are more smarter than computers in thinking process. Berland and Wilensky (2015) introduced a term *Computational perspective* which is used when a learner uses CT in other domains of life rather than computer science.

Technology is being merged with subjects with the everyday passing in current era, Students are more exposed to digital activities or programming languages now as compared to the last century. The trend of integrating digital technology with instruction in class rooms is increasing and it is being merged with curriculum directly or teaching some extra modules in class rooms in the form of computational thinking (Adell e*t al*, 2017). It was suggested that computational thinking should be integrated to STEM subjects rather than subject of computer science (Google Inc. and Gallup Inc., 2016).

Computational thinking is being merged in curriculum in many countries and some European countries have started to incorporate it (Balanskat & Engelhardt, 2014). It was also observed that many teachers have started to incorporate CT in their instruction to improve the achievements of the students (Angeli *et al*, 2016). UK introduced a set of CT courses in almost all subjects or disciplines (Brown et al, 2014). Australia have introduced CT courses in their primary and secondary schools as well development of a training setup to promote it (Falkner et al, 2014). Poland is an excellent example of computer based instructions and they are training their students in computing and problem solving skills gradually, which leads finally to make them able in analyzing problems to reach solutions (Syslo & Kwiatkowska, 2015).

Scratch programming software as intervention

LOGO was first ever programming language which was used for elementary school students (Feurzeig, Papert, & Lawler, 2011). It was mentioned by Buitrage Florez (2017) that CT skills must be introduced in elementary students to boost their cognitive skills relating to computational thinking. In the scenario some other programming environments were introduced to foster mathematical thinking such as *Toontalk* animated word which proved very helpful (Kahn *et al*, 2017). Among all of these Scratch programming emerged as most friendly for learners to think creatively and work in specific pattern in a collaborating environment (Brennen *et al*, 2014). Scratch is such a user friendly that fourth grade students learned the basic programming in just three days this is possible only as graphics are being used in it rather than textual (Funke *et al*, 2017).

Several studies concluded that scratch software equip learners to solve the mathematical problems through CT (Calco *et al*, 2015; Mormolejo & campos, 2013; sue *et al*, 2014). On the other hand scratch software enables teachers to create their modules using computational thinking as well as they are free to choose teaching style which is more in the line of CT (Benton *et al*, 2017).

Significance of the study

Computational thinking has emerged as new higher order thinking skill in past decade or more and are being exposed to many courses in different areas of education (Angeli *et al*, 2016) so it is obvious to think how CT skills can be developed (Denning,2017). Teachers are also not aware about the role and development of Computational thinking (Corradini *et al*, 2017) even in developed countries. On the other hand International society for technology in Education (ISTE) has included computational thinking as a standard along with other six standards which shows the growing trend of it in countries like USA (ISTE, 2016).

CT development models or activities, existing in different countries can never be implemented as it is in other countries due to different cultural as well as educational dimensions, it is better to develop CT skills by teachers in their students accordingly (Yadav et al., 2017).

. The present study may be addition of knowledge in regard of computational thinking particularly in Pakistan perspective. This study may be helpful for teachers, administrators as well as policy makers in Pakistan for development of the curriculum according to the needs of new era. Moreover this will be a way for researcher in Pakistan to find out its implications in different subjects and levels.

Objectives of the study

The objectives of the study were

- To investigate the prevalence of computational thinking in the elementary students in the sample
- To develop computational thinking in elementary school students through intervention of scratch software
- To explore the influence of gender differences on the development of computational thinking through the intervention of scratch software

Research Questions

The following research questions were framed to address in the study

- What level of computational thinking prevails in the sample of study and can it be developed through scratch?
- Whether intervention of scratch software in instruction has a significant contribution to foster the computational thinking of students?
- Does gender affect the development process of CT skills in elementary school students?

Social Sciences & Humanity Research Review
ISSN 3007-3170(O), ISSN :3007-3162(P)
Volume 3 issue 1,pp. 541-557
January-March 2025

RESEARCH METHOD

The study was experimental in nature and material and methods for the study are being described as follows

Population of the study

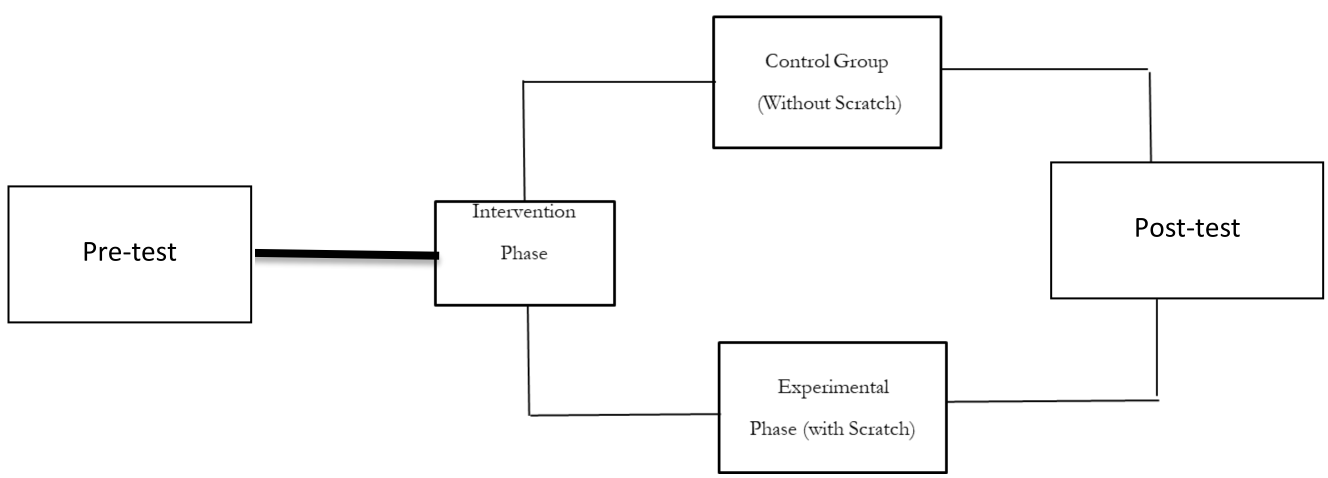
All male and female students of the district Chiniot were the population of the study.

Sample of the study

The total sample of the study was comprised of 120 participants of grade-8 students. These participants were selected through purpose sampling technique. Half of the students were male and the other half was female students.

Research Design

True experimental research design will be used for the study.



Variables of the study

The independent variables of the study were

1. Intervention of scratch software for development of computational thinking
2. Gender of the participants

The dependent variable will be

1. Development of computational thinking 2. Academic performance

Data collection tools

The scale developed by Korkmaz, Cakir and Ozden (2015) was used for measurement of computational thinking skills. The scale has total 22 items with five factors. Cronbach Alpha was calculated 0.809 for the scale which shows the scale is reliable. The factors Cronbach Alpha was measured as: 0.640 for creativity, 0.762 for algorithmic thinking, 0.811 for collaboration, 0.714 for critical thinking and 0.867 for problem solving.

Procedure of the study

All students included in the sample of the study were divided into four groups. Two groups were of male students and two of female students. One group of male students as well as female students served as control group while other two groups served as experimental groups. Students were assigned to control and experimental group through random sampling technique. The means of both experimental as well as control group equated before running experiment through statistical procedures.

Three modules were prepared through scratch software based on general development of computational thinking as well as subject based intervention. Each module was administrated for three weeks and there will be total nine weeks experiment. Teachers were trained accordingly.

Data collection and analysis

The data will be collected through standard scale as well as demographics will be collected through questionnaire. The data were analyzed using following statistical tests

1. ANOVA
2. Paired sample t-test.

Delimitations of the study

Keeping in view constraints of time and finance this study will be delimited to

1. Two schools
2. Grade eight students only

RESULTS AND INTERPRETATIONS

The results on based of the data collected during experiment and analyzed to reach the conclusions are being presented here in the alignment of the objectives of the study as well as research questions.

- **Findings regarding the research question 'What level of computational thinking prevails in the sample of study and can it be developed through scratch?'**

Table1. Results Pretest-posttest of all dimensions of computational thinking

	Creativity	Algorithm thinking	Cooperativity	Critical thinking	Problem solving
Pre-test results	61.35	56.25	65.80	58.40	54.90
Post-test results	71.35	62.85	70.25	60.20	56.30
SD	12.96	9.97	13.75	11.75	8.75
t-test	5.98	5.13	2.51	1.19	1.24
Cohen's d	0.77	0.66	0.32	0.15	0.16
P-value	P<0.05	P<0.05	P<0.05	P>0.05	P>0.05

Table 1 indicates that the prevalence of computational thinking in the sample. Moreover three of five area of computational thinking indicated significant improvement i.e. creativity, algorithm and cooperativity on the other hand two area although indicated improvement in the mean values but are not statistically significant. The results also indicated that effect size of the treatment in creativity and algorithm thinking noted larger as compared to problem solving and critical thinking.

• **Findings regarding the research question 'Whether intervention of scratch software in instruction has a significant contribution to foster the computational thinking of students?'**

Table 2; Mean achievement score in experimental and control groups

Groups	Pre Test			Post test			Mean Difference
	N	X	SD	N	X	SD	
Experimental group (Scratch Intervention)	120	46	12	120	69	26	23
Control group	120	48	16	120	53	14	05

t-statistic =60.56 P-value <0.001 Cohen's d (Effect Size) =1.01

The table-2 shows that the p-value < 0.05, meaning the difference in improvement between the experimental (23%) and control (5%) groups is statistically significant. Cohen's d = 1.01, which is a large effect size, indicating that the intervention had a strong practical impact. This means that the experimental group showed a significantly higher improvement in scores compared to the control group. The intervention had a strong and meaningful effect on performance

Table3: ANNOVA Calculations

Sources of variation	Sum of squares	df	Mean Squares	F	P
Between Groups	66,480	3	22,161.00	0.35	0.612
Within Groups	151,368	476 (calculated as (120x4) -4)	318.0	-------	-----
Total	217,848	479	-------	-----	-----

A one-way ANOVA was conducted to compare the effect of the intervention on the experimental and control groups. The results showed no statistically significant difference between the groups**,** $F(1, 238) = 0.35$, $p = .612$**.** This suggests that the mean difference between pre-test and post-test scores does not vary significantly between the experimental and control groups. This can be concluded as

- Since $p > 0.05$, the difference between groups is not statistically significant**.**
- This means that while the experimental group had a greater mean improvement (23%) compared to the control group (5%), the difference is not strong enough to conclude a significant effect based on ANOVA.
- This contrasts with the earlier t-test, which showed a significant difference. The discrepancy might be due to sample size, variance assumptions, or different test sensitivities.

Tukey's HSD post hoc test is applied to determine which groups significantly differ from each other after ANOVA. This test was conducted to compare all possible group pairs and provide significance levels for each comparison.

Table 4: Tukey's HSD pairwise comparisons among groups (N = 120 per group

Comparison (Group 1 vs. Group 2)	Mean Difference	p-value	Significant (p < .05)
Pre-test Experimental vs. Pre-test Control	−2	0.821	No
Pre-test Experimental vs. Post-test Experimental	−23	< .001	Yes
Pre-test Experimental vs. Post-test Control	−7	0.013	Yes
Pre-test Control vs. Post-test Experimental	−21	< .001	Yes
Pre-test Control vs. Post-test Control	−5	0.133	No
Post-test Experimental vs. Post-test Control	+16	< .001	Yes

The Tukey HSD post hoc comparisons indicate several significant differences between specific group means:

- Baseline Comparison: There was no significant difference between the experimental and control groups at pre-test (Mean experimental =46 vs. Mean control =48; $p = .821$). This suggests the two groups started at comparable levels before the treatment.
- Experimental Group Improvement: The experimental group's score increased significantly from pre-test to post-test. The post-test experimental mean ($M = 69$) was 23 points higher than its pre-test mean ($M = 46$), a difference that was statistically significant ($p < .001$). This implies that the intervention had a positive effect on the experimental group's performance.
- Control Group Change: The control group's change from pre-test to post-test was not significant**.** The post-test control mean ($M = 53$) was only 5 points higher than the pre-test control mean ($M = 48$), and this difference did not reach statistical significance ($p = .133$). In other words, the control group did not show a significant improvement over time.
- Post-test Group Comparison: At the post-test, the experimental group scored significantly higher than the control group ($M = 69$ vs. $M = 53$, respectively). This 16-point advantage for the experimental group was statistically significant ($p < .001$), indicating that the experimental treatment led to substantially better outcomes compared to the control condition by the end of the study.
- Additional Pairwise Differences: The experimental group's post-test mean was also significantly higher than both pre-test means (compared to the pre-test experimental and pre-test control means, $p < .001$ in both cases). Additionally, the control group's post-test mean was significantly higher than the experimental group's pre-test mean (a 7-point difference, $p = .013$). These findings reinforce that any comparison involving the experimental group's post-test score showed a significant increase over the other group means, whereas differences not involving the post-test experimental group (e.g., the two pre-test means, or the control group's pre vs. post means) were not significant.

- **Findings about Research question, "Does gender affect the development process of CT skills in elementary school students?"**

  The results about impact of gender difference in development of computational thinking in elementary school students were also analyzed on the basis of their performance which is being presented in the table-5.

Table 5: Results of Gender impact

Comparison	Mean Difference	t-statistic	p-value	Effect Size (Cohen's d)
Pre-test (Male vs. Female)	4	1.5	0.14	0.27
Post-test (Male vs. Female)	6	1.61	0.11	0.29

1. Pre-Test Gender Comparison

- t-statistic **=** 1.50
- p-value **=** 0.14
- Cohen's d **=** 0.27 **(**Small effect size)

This data shows that

1. There was no statistically significant difference in pre-test scores between males and females ($p>0.05$).
2. The effect size ($d=0.27$) is small, meaning the gender difference was minimal before the intervention.

2. Post-Test Gender Comparison

- t-statistic = 1.61
- p-value = 0.11

- Cohen's d = 0.29 (Small effect size)

This means that

1. The post-test scores were not significantly different between males and females ($p>0.05$), meaning gender differences did not strongly impact performance after the intervention**.**
2. The effect size ($d=0.29$) is still small, indicating some difference but not a strong practical impact. Which can be concluded as

*"There is no significant difference is established in pre-test scores as well as in post-test scores. Effect sizes (Cohen's d) indicate only a small effect****,*** *meaning gender differences did not strongly influence test performance"****.***

DISCUSSION AND CONCLUSION

Our results shows that all of the five factors of the computational thinking have mean above 50% before intervention of the scratch which shows that prevalence of the computational thinking in the sample. The posttest results (Table-1) after the intervention of the scratch indicated that three out of the five main factors of the computational thinking improved significantly while rest two factors although not improved significantly but mean improved. The study revealed that students improved significantly in creativity, Algorithm thinking and cooperativity which is in agreement with in existing studies (Yildaz Durak, 2020). On the other hand effect size of critical thinking as well as problem solving skill is small and statistically not significant

The modules of mathematics were taught students to develop their computational thinking as well as improvement in the instruction in the class room. The results (Table -2) indicated that emerging scratch classroom instruction enhanced academic scores of the students significantly. Zhang & Nouri (2019) also concluded that scratch have significant impact on academic performance of the students so the study is in alignment with it.

As far as gender differences the results indicated that there is no significant relation between genders in development of computational thinking. These finding are in alignment with the other existing studies.

The conclusion of the present study can be summarized as follows

1. Computational thinking can be developed with the help of scratch software induction in the classroom instruction.
2. Academic performance of the students positively and significantly affected with teaching through scratch
3. There is no gender differences observed in terms of computational thinking as well as academic performance through scratch.

RECOMMENDATIONS

1. The present study was designed for 9 weeks only. it is recommended that in future scratch software should be added at least for a year to reach reliable results

2. Scratch as well as other programming software should be added in instruction for comparison

3. Modules of the study should be introduced in variety of the subjects rather than mathematics only.

LIMITATIONS

The study was limited to the two schools and short time span as well as mathematics subject for module preparations through scratch.

REFERENCES

Adell, J., Esteve, F., Llopis, M. Á., & Valdeolivas, M. G. (2017). El pensamiento computacional en la formación inicial del profesorado de infantil y primaria (Computational thinking in the initial training of children and primary school teachers). *Proceedings of the XXJornadas Universitarias de Tecnología Educativa JUTE 2017. Aulas y Tecnología Educativa en evolución, Burgos, Spain* (pp. 151-158).

Angeli, C., Voogt, J., Fluck, A., Webb, M., Cox, M., Malyn-Smith, J., & Zagami, J. (2016). A K-6 computational thinking curriculum framework: implications for teacher knowledge. *Educational Technology & Society, 19*(3), 47-58.

Balanskat, A., & Engelhardt, K. (2014). *Computing our future: Computer programming and coding-priorities, school curricula and initiatives across Europe*. European Schoolnet.

Benton, L., Hoyles, C., Kalas, I., & Noss, R. (2017). Bridging primary programming and mathematics: Some findings of design research in England. Digital Experiences in Mathematics Education, 3(2), 115–138. doi:10.1007/s40751-017-0028-x

Brennan, K., Balch, C., & Chung, M. (2014). Creative computing. Retrieved from http://scratched.gse.harvard.edu/guide/

Brown, N. C., Sentance, S., Crick, T., & Humphreys, S. (2014). Restart: The resurgence of computer science in UK schools. *ACM Transactions on Computing Education (TOCE), 14*(2), 9

Buitrago Flórez, F., Casallas, R., Hernández, M., Reyes, A., Restrepo, S., & Danies, G. (2017).

Changing a generation's way of thinking: Teaching computational thinking through programming. Review of Educational Research, 87(4), 834–860.

Calao, L. A., Moreno-León, J., Correa, H. E., & Robles, G. (2015). Developing mathematical thinking with Scratch. In G.Conole, T. Klobučar, C. Rensing, J. Konert, & E. Lavoué (Eds.), Design for Teaching and Learning in a Networked World. Lecture Notes in Computer Science, vol 9307 (pp. 17–27).

Corradini, I., Lodi, M., & Nardelli, E. (2017). Conceptions and Misconceptions about Computational Thinking among Italian Primary School Teachers. In Proceedings of the 2017 ACM Conference on International Computing Education Research (pp. 136–144). ACM.

Denning, P. J. (2017). Remaining trouble spots with computational thinking. *Communications of the ACM*, *60*(6), 33-39.

Falkner, K., Vivian, R., & Falkner, N. (2014, January). The Australian digital technologies curriculum: challenge and opportunity. In *Proceedings of the Sixteenth Australasian Computing Education Conference-Volume 148* (pp. 3-12). Australian Computer Society, Inc.6

Feurzeig, W., Papert, S. A., & Lawler, B. (2011). Programming-languages as a conceptual framework for teaching mathematics. Interactive Learning Environments, 19(5), 487–501. doi:10.1080/10494820903520040

Funke, A., Geldreich, K., & Hubwieser, P. (2017). Analysis of Scratch projects of an introductory programming course for primary school students. In 2017 IEEE global engineering education conference (EDUCON) (pp. 1229–1236). IEEE. doi:10.1109/EDUCON.2017.7943005

Grover, S., & Pea, R. (2013). Computational thinking in K–12: A review of the state of the field. *Educational Researcher, 42*(1), 38–43. doi:10.3102/0013189X12463051

Google Inc., & Gallup Inc. (2016). Trends in the state of computer science in U.S. K-12 schools. In Retrieved from http://goo.gl/j291E0.*Computers & Education*, *126*,

International Society for Technology in Education (ISTE). (2016). ISTE national educational technology standards (NETS) for students. Eugene, OR: International Society for Technology in Education.

Kahn, K., Sendova, E., Sacristán, A. I., & Noss, R. (2011). Young students exploring cardinality by constructing infinite processes. Technology, Knowledge and Learning, 16(1), 3–34. doi:10.1007/s10758-011-9175-0

Korkmaz, Ö., Çakır, R., & Özden, M. Y. (2015). Computational thinking levels scale (ctls) adaptation for secondary school level. *Gazi Journal of Educational Science, 1*(2), 143-162

Korucu, A. T., Gencturk, A. T., & Gundogdu, M. M. (2017). Examination of the computational thinking skills of students. Journal of Learning and Teaching in Digital Age, 2(1), 11–19. https://dergipark.org.tr/en/pub/joltida/issue/55466/760079

Shute, V.J., Sun, C. & Asbell-Clarke, J., (2017). Demystifying computational thinking. Educational Research Review, 22, 42-158.Spencer,

Sysło, M. M., & Kwiatkowska, A. B. (2015, September). Introducing a new computer science curriculum for all school levels in Poland. In *International Conference on Informatics in Schools: Situation, Evolution, and Perspectives* (pp. 141-154). Springer, Cham. *Communications of the ACM*, *49*(3), 3

Yadav, A., Stephenson, C., & Hong, H. (2017). Computational thinking for teacher education. Communications of the ACM, 60(4), 55–62. https://doi.org/10.1145/2994591

Wing, J. M. (2006). Computational thinking. *Communications of the ACM*, *49*(3), 33-35.

Wing, J. M. (2008). Computational thinking and thinking about computing. *Philosophical Transaction of the Royal Society*, *366*(1881), 3717-3725 3–35.

Wing, J. M. (2008). Computational thinking and thinking about computing. *Philosophical Transaction of the Royal Society*, *366*(1881), 3717-3725 3

Zhang, L., & Nouri, J. (2019). A systematic review of learning computational thinking through Scratch in K-9. Computers & Education,141,103607. doi: 10.1016/j.compedu.2019.103607.10 Damira Belessova et al.