Computational Thinking in Agricultural STEM-Based Project:
A Case Study on the Impact of the Magnetcode Application Among Zambian Educators

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Abstract
In the rapidly evolving landscape of education, the integration of computational thinking (CT) into STEM (Science, Technology, Engineering, and Mathematics) curricula has emerged as a pivotal strategy for enhancing educators in teaching and learning and preparing future generations for the demands of the 21st-century workforce. This study investigates the impact of the Magnetcode application on enhancing computational thinking (CT) skills among educators in Zambia. Open-ended interview, pre-test and post-test designs were employed to measure the impact and the effectiveness of computational thinking in agricultural STEM-based projects to Zambian educators in terms of knowledge and understanding of CT elements, basic design coding, circuit simulation, and the application of Magnetcode Microcontroller in STEM project. The results demonstrated significant improvements in all assessed areas. The percentage improvement ranges from 1.31% to 2.5%, with the highest improvement observed in the application of the Magnetcode microcontroller. The mean for the pre-test was significantly different from the test value of 0, with a mean difference of 27.69 and a 95% confidence interval of 25.39 to 29.99, supported by a t-value of 25.66 ($p < .001$). Integrating computational thinking and coding into STEM educational curricula can enhance teachers' understanding and skills in implementing STEM education in Zambia.

Keywords: Computational Thinking, Magnetcode Application, Microcontroller, STEM Education

Introduction

Computational thinking has become a vital skill in education, especially in the fields of science, technology, engineering, and mathematics (STEM)(Kong & Abelson, 2019; Thissen, 2022). With the increasing demand for digital literacy and problem-solving abilities, educators need to integrate computational thinking into their teaching practices (Ezeamuzie, 2023).

The African Union's Agenda 2063 emphasizes the critical role of STEM (Science, Technology, Engineering, and Mathematics) and ICT (Information and Communication Technology) in driving socio-economic transformation across its member states. The Southern African Development Community (SADC) countries have held multiple forums to identify areas of cooperation aimed at enhancing the status of STEM education for the collective benefit of all member states. This collaborative approach is essential for fostering innovation and economic growth across the region [5].

The development of the STEM Education curriculum in Zambia commenced in December 2019, following the Ministry of General Education's receipt of cabinet approval to implement the curriculum in 52 pilot secondary schools (Oliver et al., 2022). A transitional curriculum was designed based on the 2013 Zambia Educational Curriculum Framework. The primary rationale for establishing STEM schools in the contemporary education system and industry is that it provides students with holistic worldviews, fosters innovation, and drives the creation of new products and processes crucial for economic sustainability. According to Phiri (2022), STEM education is crucial for facilitating economic development, enhancing international competitiveness, and fostering innovation. By emphasizing hands-on experimentation, STEM education enables learners to transition from abstract concepts to real-world applications (Oliver et al., 2022; Phiri et al., 2022).

The current state of STEM education in Zambia is not ideal, with limited resources and trained professionals. Many educators struggle to engage students in these subjects, leading to a lack of interest and poor academic performance (DeGhetto et al., 2016). This has created a demand for new and innovative teaching methods that can make STEM education more accessible and engaging for students (Imms & Kvan, 2021) . According to Oliver (2022), teachers in Zambia have improper training in STEM curriculum and a lack of understanding of how to integrate teaching and learning materials such as coding and programming in STEM education (García-Peñalvo, 2018).

Therefore, integrating computational thinking into STEM education is essential for helping teachers develop critical skills needed for success in a technology-driven world. According to Mulenga and Kabombwe (2019), Zambian teachers are willing to participate in STEM curriculum training development and a need for more inclusive processes in STEM curriculum development to ensure effective implementation and teacher engagement (Mulenga & Kabombwe, 2019). This includes skills such as logical reasoning, algorithmic thinking, and problem-solving, which are crucial in STEM fields such as engineering, computer science, and data analysis (Meseguer & Serrano, 2024; Rabiee & Tjoa, 2017). Therefore, this research aims to investigate the impact of the Magnetcode application on enhancing computational thinking skills among Zambian educators and to understand its effectiveness in integrating computational thinking into STEM education.

Research Objective

To evaluate the impact of the Magnetcode application on enhancing computational thinking skills among Zambian educators and to understand its effectiveness in integrating computational thinking into STEM education.

Research Question

How does the use of the Magnetcode application influence the computational thinking skills of educators in Zambia, and how effective is it in facilitating the integration of computational thinking into STEM education?

Literature Review

Computational thinking (CT) skills involve systematically solving sub-problems through decomposition, allowing for efficient abstraction, planning, and coding processes that follow a linear path towards a solution (Shute et al., 2017). The Magnetcode application utilizes block-based programming languages, enabling users to design programming algorithms by dragging and dropping program chunks, known as blocks (Weintrop & Wilensky, 2015). Through the process of learning programming and coding, educators can expose students to computational skills that involve critical thinking and creative problem-solving. Coding is widely believed to enhance problem-solving abilities, especially in STEM projects (Grover & Pea, 2017; Thissen, 2022; Voon et al., 2023). According to Matsuzawa and colleagues (2017), block-based languages offer an advantage in understanding text-based languages, allowing teachers to encourage students to focus more on high-level algorithm creation using coding. By improving their knowledge of computational thinking (CT) skills, teachers can better guide students in developing these essential abilities in teaching and learning.

Figure 1 illustrates the consolidation of the integration of computational thinking skills in an Agricultural STEM-based project, highlighting a process that educators in Zambia can employ. It begins with identifying a complex problem within the agricultural STEM domain. This problem is then addressed through the process of abstraction and decomposition, which involves simplifying the problem by focusing on its essential features and iteratively breaking it down into more manageable sub-problems. This spiral process of abstraction and decomposition helps in systematically understanding and approaching the problem.

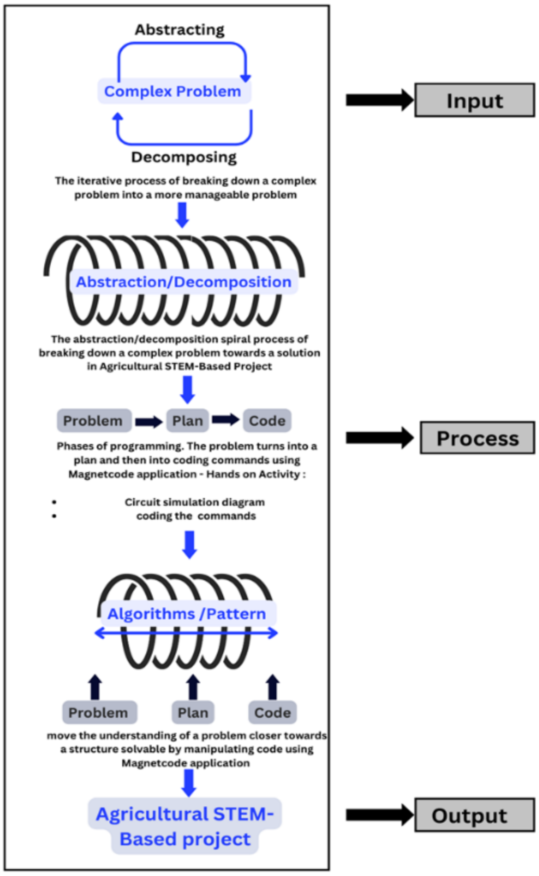

Figure 1: Consolidation of the Integration Computational Thinking Skills in Agricultural STEM-Based Project

The problem-solving phases are divided into three steps: defining the problem, developing a step-by-step plan, and translating the plan into actionable commands or code. Tools like Magnetcode can be used for practical hands-on activities such as circuit simulation and coding commands. Figure 2 shows the flow chart to recognize patterns and develop algorithms to solve the problems. In this phase, the educators are involved in continuous refinement and iteration of the problem-solving process to enhance understanding and find effective solutions.

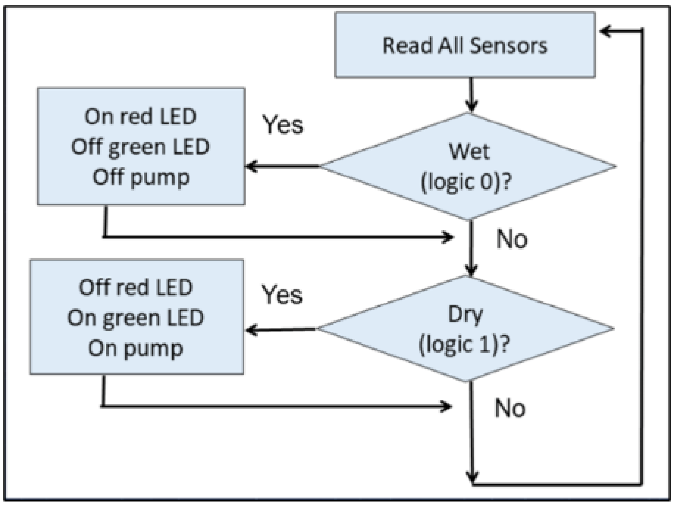

Figure 2: Smart Irrigation Flow Chart

The process of abstraction and decomposition involves simplifying a complex problem by focusing on its essential features and then iteratively breaking it down into more manageable sub-problems. The coding process using Magnetcode applications using block-based language is easy to use (Wan Nurlisa et al., 2023). The block-based language has a lower barrier to programming compared with text-based language (Glushkova, 2016). The block-based command for agricultural STEM-based projects is shown in Figure 3.

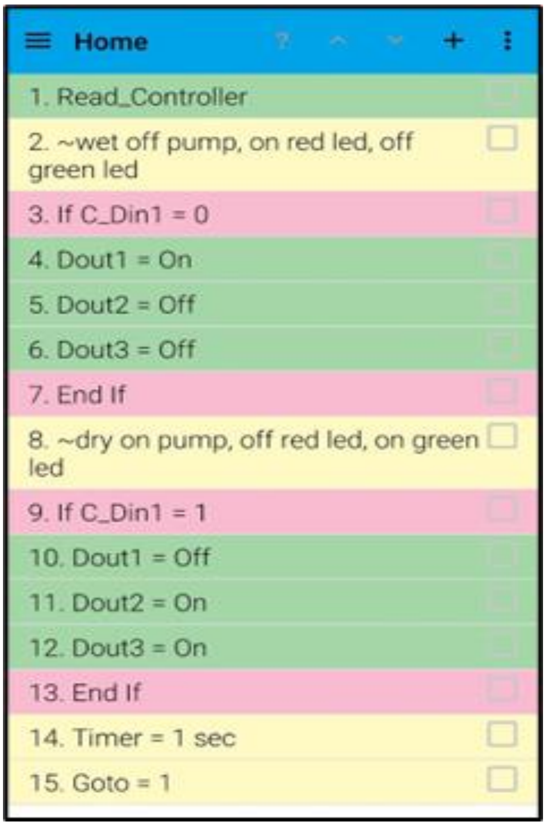

Figure 3: The Coding Command for Smart Irrigation System in Agricultural STEM-Based Project

This spiral approach in Figure 1, allows for a systematic and comprehensive understanding of the problem. The problem-solving phases within this process include defining the problem clearly, developing a detailed plan or strategy to address it, and translating the plan into a simulation diagram in Magnetcode application. Figure 4 shows the circuit simulation and command coding for the whole system of the smart irrigation system project. Through this iterative cycle of abstraction, decomposition, planning, and coding, complex problems become more approachable and solvable and suitable for the integration of computational thinking in STEM education.

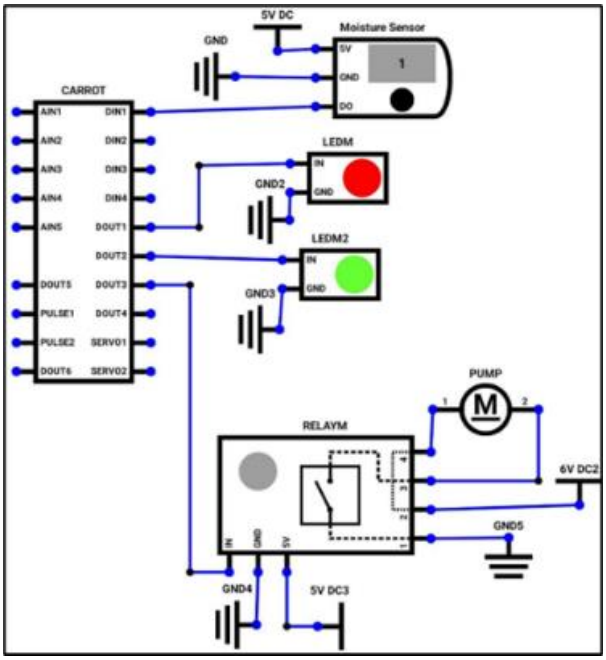

Figure 4: The Circuit Simulation for Smart Irrigation System
in Agricultural STEM-Based Project

Methodology

This study used a quantitative and qualitative approach with a case study design. The researcher employed a one-group pre-test and post-test design and open-ended interview to evaluate the effectiveness of the Magnetcode application in enhancing computational thinking skills among educators at Malcolm Moffat College of Education. The researcher used purposive sampling to select 16 educators who teach STEM subjects, ensuring the participants are directly involved in the areas most likely to benefit from the integration of computational thinking. The intervention consists of a workshop focused on the practical application of coding and programming through Magnetcode for agricultural STEM-based hands-on projects.

To assess the impact of integration CT using the Magnetcode application, the researcher measured the computational thinking skills of the educators before and after the workshop using standardized pre-tests and post-tests. Five-point Likert scale was used to gather the mean for the pre-test and post-test. The analysis of the data involved calculating the percentage difference between the pre and post-test results to quantify the improvement in knowledge and skills. The researcher also applied one sample t-test to these results to determine if the observed changes were statistically significant. The open-ended interview was employed to measure the impact and effectiveness of the Magnetcode application in integrating computational thinking into agricultural STEM-based projects in STEM education.

Findings and Discussion

This study investigates the impact of the Magnetcode application on enhancing computational thinking (CT) skills among educators in Zambia**.** The findings ought to answer the research objective and research question in this study. Table 1 shows the findings from the pre-test and post-test related to the knowledge and understanding of computational thinking in STEM projects using the Magnet code application.

Table 1: Knowledge and Understanding in Computational Thinking in STEM Project Using Magnetcode Application

Knowledge and understanding	N	Mean Pre-Test	Standard Deviation (SD)	Mean Post-Test	Standard Deviation (SD)	% Difference
1. Computational Thinking elements in teaching and learning.	16	2.44	0.89	3.75	0.75	1.31
2. Basic design coding in teaching and learning for STEM activities.	16	1.94	0.77	4.00	0.73	2.06
3. Circuit simulation through Computational Thinking Skills with STEM activities.	16	2.00	0.73	3.81	0.83	1.81
4. The application of Magnetcode Microcontroller in STEM projects.	16	1.56	0.63	4.06	0.77	2.5
5. The application of Magnetcode in pedagogical strategies for STEM projects.	16	1.94	0.77	4.06	0.77	2.12
6. The application of Magnetcode in teachers' activities for STEM projects.	16	1.00	0.00	4.06	0.93	3.06
7. The application of Magnetcode input Transducer (Sensor) for STEM projects.	16	1.00	0.00	3.56	0.89	2.56
8. The application of Magnetcode Output Transducer (Actuator) for STEM projects.	16	1.00	0.00	3.56	0.81	2.56

The results indicate substantial improvements in educators' understanding and application of CT elements, basic design coding, circuit simulation, and the use of microcontrollers. These enhancements are crucial for integrating CT into STEM education in Zambia. A strong foundation in CT allows educators to design and implement STEM projects that foster critical thinking, problem-solving, and algorithmic reasoning. Figure 5 shows STEM educators applying basic coding in agricultural STEM-based projects using the Magnetcode application, sensor and actuator.

Figure 5: STEM Educators Applying Computational Thinking Skills Using the Magnetcode Application, Sensor and Actuator in Agricultural STEM-Based Project

The findings also illustrated the notable increase in basic design coding skills, from the mean value of 1.94 to 4.00, underscores the application's effectiveness in providing practical coding experience, which is vital for creating engaging and interactive lessons. Figure 6 illustrates the outcome of the workshop in coding and circuit simulation diagrams. The STEM educators are able to design their own circuits using the Magnetcode application before they create the real project.

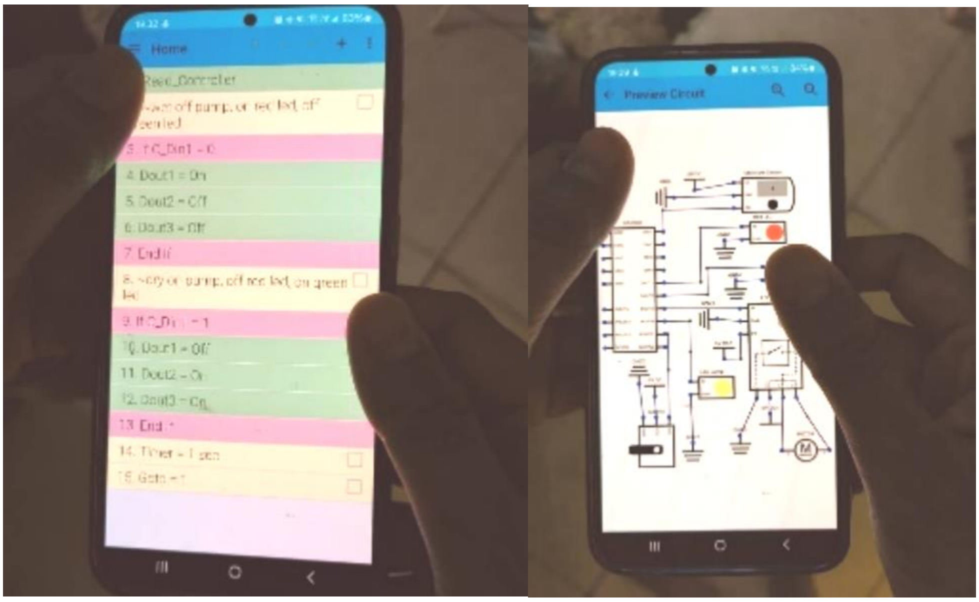

Figure 6: Coding and Circuit Simulation Diagram for Smart Irrigation Project

Furthermore, the improvement in circuit simulation skills, with mean value rising from 2.00 to 3.81, equips educators to better prepare students for real-world engineering and technology challenges. The most significant gain was in the application of the Magnetcode Microcontroller, with value increasing from 1.56 to 4.06, indicating a substantial boost in hands-on experience and confidence in using advanced STEM tools. Figure 7 shows the outcomes from the workshop where the STEM educators were able to integrate computational thinking skills in their agricultural STEM-based project using the Magnetcode application.

Figure 7: Functioning Prototype for Smart Irrigation Project

The researcher also analyses the results of the workshop with one sample t-test. Table 2 shows the result obtained.

Table 2: One-Sample t-Test

	t	df	Significance		Mean Difference	95% Confidence interval of the Difference	
			One-Sided p	Two-Sided p		Lower	Upper
Mean Pre-Test	25.66	15	<.001	<.001	27.69	25.39	29.99
Mean Pre-Test	30.40	15	<.001	<.001	48.69	45.27	52.10

The t-test results indicate a significant impact of the integration of computational thinking in agricultural STEM-based projects among Zambian educators. The mean for the pre-test was significantly different from the test value of 0, with a mean difference of 27.69 and a 95% confidence interval of 25.39 to 29.99, supported by a t-value of 25.66 ($p < .001$). These results indicated that before the workshop, educators had a moderate understanding of computational thinking and integration of the Magnetcode application in the agricultural STEM-based project. However, the mean for the post-test shows an even larger difference of 48.69 with a 95% confidence interval of 45.27 to 52.10, supported by a t-value of 30.40 ($p < .001$). Both one-sided and two-sided p-values for both tests are less than 0.001, indicating that the results are statistically significant. These results indicate the Magnetcode application had a profound impact on enhancing the educators' computational thinking skills especially for the integrating the STEM project into subject-based contents.

The open-ended interview findings also supported the impact and the effectiveness of computational thinking in agricultural STEM-based projects using Magnetcode application as summarized in Figure 8.

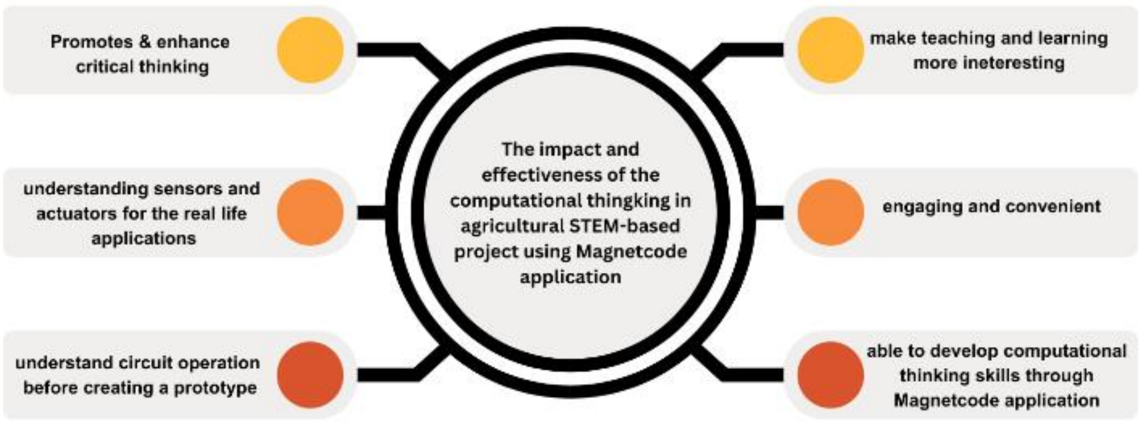

Figure 8: Findings From the Open-Ended Interview

The open-ended interview findings showed that the Magnetcode application in agricultural STEM-based projects can promote and enhance critical thinking especially in understanding circuit operation before creating a project. The indicators reported from open-ended interviews for Respondent 1, Respondent 2, Respondent 3 and Respondent 4 as stated below:

> *R1: "Magnetcode promotes critical thinking"* ***Interview: 26.02.24***
> *R2: "It's enhances critical thinking"* ***Interview: 26.02.24***
> *R3: **"**Magnetcode simulation is interested in that it enables students understand the operation of the circuit before the prototype is made"* ***Interview: 26.02.24***

The findings imply that the participants agreed the Magnetcode circuit simulation in Agricultural STEM-based project activities had an impact on their knowledge and skills in computational thinking. Thus, the findings illustrated that integrating computational thinking in agricultural STEM-based projects promotes critical thinking and makes teaching and learning more interesting.

The effectiveness of integrating computational thinking in Magnetcode features was also reported from the indicators from open-ended interviews from R1, R2, R3 and R4 as below:

> *R1: "enables me to understand the impact of transducers in everyday life"* ***Interview: 26.02.24***
> *R2: "to understand the real life application of various examples of transducers"* ***Interview: 26.02.24***
> *R3: "enables learners to develop the skills of programming which is the basis of CT"* ***Interview: 26.02.24***
> *R4: "ideal for programming / coding. This enhances CT as it is done easily on phone"* ***Interview: 26.02.24***

The open-ended interview findings also revealed that the integration of computational thinking in Magnetcode application can develop the understanding of the transducers and actuators for STEM projects. The participants agreed that Magnetcode features are relevant in pedagogical strategies for agricultural STEM-based projects and have an impact on their knowledge and skills in integrating computational thinking in teaching and learning. The findings illustrated the effectiveness of using the application in developing computational thinking, which is foundational for critical thinking and ease of programming on a smartphone.

Conclusion

Integrating computational thinking skills among STEM educators is vital in creating a new teaching strategy in STEM education. The application of Magnetcode as a computational thinking tool in STEM subject-based content such as science, agricultural science, engineering and mathematics, thereby broadening students' understanding and interest in STEM fields. Overall, the study highlights that by enhancing educators' CT skills through tools like Magnetcode, the quality of STEM education in Zambia can be significantly improved, preparing students for future innovations and problem-solving in the STEM landscape.

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