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Assisting School Teachers in Developing and Implementing Learning Modules Infused with Computational Thinking Principles

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Abstract: This community service activity program aims to guide school teachers to infuse CT principles into the learning modules and to implement their CT-infused modules in their classes. The methods for implementing community service activities were workshops and mentoring activities. The target of the activity was pre-school, elementary, and junior-high school teachers at School Foundation of Yohanes Gabriel sub-District Tuban. The instruments used to collect data were a survey, observation sheets, and learning-module documents. The data were analyzed to describe the teachers' abilities to create CT-infused modules and their skills to carry out these modules in their instructional practices. The results of this program showed that the teachers understood CT principles and taxonomy and could create appropriate teaching modules infused with CT principles. It implies that this community service program could improve teachers' teaching skills through their efforts to integrate computational thinking into their instructional practices.

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Introduction

Students in the 21st century must have the skills, knowledge, and attitudes necessary to solve increasingly complex problems and face challenges in this changing world (Adeoye & Jimoh, 2023). Responding to the conditions of the 21st-century disruption, the Ministry of Education and Culture launched a new competency in the Merdeka Curriculum (MC) called computational thinking (CT). In addition, the learning achievements stated in the MC of kindergarten, primary and secondary education levels are to be translated into learning objectives, which could be infused with CT (Aditomo, 2022). The Government policy implies that students' learning of a school subject should not be limited to gaining knowledge and skills of the subject itself. However, it should also enable students to use them in real-life problem solving.

According to the MC, school students must be accustomed to doing problem-solving exercises. They should be equipped with CT, which enables them to solve problems effectively (Andrian & Hikmawan, 2021). To help students with problem-solving skills, teachers must first understand CT concepts and be able to infuse CT principles into the subjects. Wing (2011) argues that CT is a thinking process in formulating problems and their effective solutions. In the school setting, CT does not have to be taught as a separate subject, but it can be infused into all subjects (Caeli & Yadav, 2020; Lim & Chen, 2021; Romero et al., 2022; Weigend et al., 2019; Yang et al., 2018). The previous studies on integrating unplugged CT into school curriculum showed that teachers were satisfied and students were

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helped to learn the lessons. School teachers, therefore, need to be equipped with CT knowledge and skills to apply it in school subjects. This practice usually includes preparing lessons, executing the lessons, and evaluating the results (Rich & Yadav, 2019).

Learning from the fact that not all teachers in Yohanes Gabriel schools in Tuban are well equipped with CT knowledge and the necessary skills (such as problem-solving, creating CT-infused learning modules, and implementing them in the teaching and learning activities in class), the team designed the community service program to assist the school teachers in developing school learning modules infused with CT principles. The program provided the teachers with guidance to understand the basic concepts of CT and infuse them into the subjects they teach. In so doing, they could also provide their students with CT skills to solve complex problems in everyday life (Standl, 2017).

This Government-funded community service program was carried out to assist the school teachers of Yohanes Gabriel in Tuban in developing learning modules infused with CT principles. The developed CT-infused learning modules were first tried in micro-teaching before being implemented in real classroom teaching. Through these CT-infused learning modules, the students could be equipped with CT skills to solve everyday problems effectively and systematically. This community service program indirectly supported the achievement of the Government policy in education.

Method

The community service was carried out unplugged, that is, developing the teachers' CT skills and training them to solve CT questions without using a computer or electronic device (Caeli & Yadav, 2020). This community service also provided assistance for the teachers in developing one CT-infused learning module, which was to be implemented in micro-teaching and real classrooms. Thus, these community service activities used workshops, focus group discussions and mentoring.

To accommodate the development and implementation of CT-infused learning modules, the current community-service program was designed in the following stages: (a) seminars and workshops on CT concepts and application, (b) assistance in the development of CT-infused learning modules, and (c) assistance in microteaching and real-classroom practices. The stages are described as follows:

The first stage: Seminar and workshop

The seminar was first carried out and attended by 5 kindergarten teachers, 15 elementary teachers, and 10 junior high school teachers of Yohanes Gabriel Foundation sub-District Tuban. The resource persons and facilitators of the seminar were the chairman and all team members. The seminar presented four topics: 21st-century literacy, four corner-stone concepts of CT, the position of CT in the MC, and problem-solving with CT. The MC focuses on developing 21st-century skills, such as critical thinking, creativity, collaboration, communication, problem-solving and digital literacy. CT is one of the new literacies of the 21st century and is increasingly considered a critical skill for academic and career success. Lockwood and Mooney (2017) argue that CT is a vital 21st-century skill. Knowledge of the four main areas—decomposition, pattern recognition, abstraction, and algorithmic design—is required to help teachers and students solve problems effectively and efficiently.

Following the seminar was the workshop, in which the teachers were guided to solve CT questions according to the level of the students being taught. This workshop aimed to train the teachers to solve CT questions relevant to their students' level.

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The second stage: Assistance in the development of CT-infused learning modules

In the second stage, the teachers were assigned to choose a topic in their subject and to develop a module that was to be infused with CT principles. A CT-infused module model and CT taxonomy were discussed to help them compose their own modules. Each MC course's syllabus was given to the respective teachers. The teachers were given one month to develop their modules at home. They were given opportunities to ask questions and consult the team about problems encountered in developing their CT-infused learning modules. The developed modules were submitted to the team for feedback. The modules with feedback were sent back to the respective teachers for revision.

This assistance aimed to guide the teachers to infuse CT principles into their learning modules. The MC allows teachers to develop learning achievement in the learning modules (Capaian Pembelajaran pada Pendidikan, 2022). Learning objectives, instructional materials, learning strategies, exercises, and assessments must be done by teachers. The teachers practised infusing these instructional elements with CT principles.

The Third Stage: Assistance in micro-teaching and real-classroom practices

The revised CT-infused modules were implemented in online micro-teaching sessions. All teachers were given chances to conduct micro-teaching and received feedback. The team, equipped with a micro-teaching evaluation form, observed, and noted the micro-teaching activities. With the feedback received during the micro-teaching, the teachers were ready to implement CT-infused modules in their real classrooms. Each teacher then taught the revised CT-infused module in his/her respective course and school. Equipped with an evaluation rubric, each team member observed several different teachers in different levels of classes and schools. Five components were noted: relevance between the topic and learning objectives, teaching delivery, classroom interaction, and CT infusion. Feedback on these components was shared with the teachers.

These three stages were carried out to help the teachers develop their CT-infused learning modules and implement them in their real classrooms. The data were collected using a survey, observation sheets and learning-module documents. The data taken from the survey were quantitatively described, while the data from the observations and the learning module documents were qualitatively described.

Result and Discussion

The findings and discussion of this community service are elaborated into two parts: the development of CT-infused modules and the implementation of CT-infused modules in micro-teaching and real classroom teaching. The data were taken from observation and documents. The observation data were obtained from seminar and workshop activities, micro-teaching and real class teaching activities. The documents consist of CT-infused learning modules applied in micro-teaching and real-class teaching. These data were used to reveal the teachers' abilities to develop CT-infused modules and their skills to implement the CT-infused modules in teaching.

Development of CT-infused modules

The data obtained from the seminar and workshop sessions revealed the teachers' knowledge about CT. To develop CT-infused modules, the teachers need sufficient knowledge about CT principles. An initial survey about their entry-level knowledge was administered to determine whether the teachers had sufficient related knowledge. The survey results showed that most teachers (76.44%) had sufficient common knowledge about CT: the pioneers, the concept of CT, and the starting time of CT socialization.

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Slightly more than half of the teachers (57.15%) were familiar with the four key concepts of CT. They knew the number of CT principles and the concepts of each CT principle: abstraction, algorithm, decomposition, and pattern recognition. They understood that computational thinking encompasses skills and processes that enable students to navigate complex problems. 52.7% of teachers had this knowledge concerning the knowledge of CT applications. They knew how to implement CT principles to solve problems. Fifteen out of twenty-eight teachers understood that CT could be used to solve real-life problems and be learned plugged and unplugged. Four out of twenty-eight teachers knew that CT principles are similar to those involved in computer science to solve problems. Less than half of the teachers (34.5%) knew that CT is included in the MC. Only seven teachers knew that CT is officially stated in the MC. Most teachers did not know that CT could be integrated into school subjects of all levels. Less than half of the teachers (48.3%) could solve CT problems. The analysis showed that only four teachers could correctly solve CT problems for junior high school levels. More than half of the teachers could correctly solve CT problems for primary school levels. Table 1 summarizes the results of the initial survey.

Table 1. Results of the initial survey

No	Components	Initial Survey : Correct responses
1	Common knowledge of CT	76.44%
2	The four principles of CT	57.15%
3	The application of CT	52.7%
4	The Merdeka Curriculum (MC) and CT	34.5%
5	Problem-solving with CT principles	48.23%

The entry-level knowledge of CT did not support the teachers in developing their learning modules. There were many areas for improvement in their initial learning modules related to the learning objectives, teaching delivery, classroom interaction, and CT infusion. The learning objectives were not properly formulated according to the learning achievement stated in the CM. Most of their learning objectives were not completely stated with condition and degree. In addition, the competencies were lower-order thinking skills (LOTS). Operational verbs stated in Bloom taxonomy (Anderson et al., 2001) was not appropriately and orderly used in the learning objectives. Almost all teaching delivery stated in the initial modules was dominated by conventional teacher-centred learning. Student-centred approach was not applied. Group work was rarely applied. The class activities were mostly conducted by the teacher lecturing and the students doing exercises. Such activities led to one-way classroom interaction, i.e., teacher to students. Engaging and empowering students in learning (Tang, 2023) were less expressed in the initial modules.

There were efforts on the part of the teachers to infuse CT principles into the initial learning modules; however, many of the learning objectives, learning activities, and exercises did not explicitly reveal any of the CT principles. Some of the weaknesses in the initial learning objectives were related to the broad topic, non-action verbs, and focus of the objectives (Melton, 2014). Some teachers did not break down a broad topic into manageable components. Besides, instead of using measurable operational verbs, the learning objectives used non-operational verbs such as *understand*, *know*, and *follow*. Some objectives also focused on learning processes or activities instead of learning results. These weaknesses resulted in an unclear infusion of CT principles in the themes of school subjects, including descriptions of learning activities and exercises.

Different from the initial learning modules, the revised learning modules were clearly infused with CT principles. Action verbs such as *analyse*, *identify*, and *write* were used to

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explain the components of the broad topic in the learning objectives, instruction materials, and learning activities. The learning objective stated "*Given a text, students are able to identify the tools of making iced tea (Decomposition), "Given a text, students are able to write the steps of making iced tea correctly (Correctly).*" The learning activities were explicitly infused with CT principles. The description of learning activities was written *"After students observe the video, the teacher asks: "What do you need to make a glass of iced tea?" (Decomposition & Abstraction) "Do you need a spoon to make a glass of iced tea?" (Decomposition & Abstraction) "What ingredients do you provide?" (Decomposition)."*

Implementation of CT-infused modules in micro-teaching and real classroom teaching

Having revised their CT-infused modules, each participant tried it out in the online micro-teaching session, supervised by the team. The team, equipped with a micro-teaching evaluation form, observed and noted the micro-teaching activities. The observation on the micro-teaching activities showed that CT infusion in instructional activities was not done in the junior high school music class and in some primary school content subjects. These teachers should have revised the initial learning modules with the given feedback. As a result, they used the unrevised learning modules in the micro-teaching. The other teachers revised the initial learning modules with the given feedback and practised implementing the CT-infused modules in micro-teaching.

The team also noticed that some feedback related to classroom language, classroom management, and teaching delivery was needed from the micro-teaching activities. The language used in classroom management, like 'sequencing, ' is usually used to express algorithms (i.e., first of all, next, finally, the last thing), which was not explicitly spoken. Next, the questions raised during micro-teaching were dominated by factual questions, while convergent and divergent questions were less used, though they were required to solve complex problems (Shettar et al., 2020). In addition, since lectures and question-and-answer were mostly used during the micro-teaching activities, the teachers were also given feedback to use group work and discussion in the learning-teaching activities. Finally, classroom management could not be well observed because the micro-teaching was done online. The class interaction could not be properly observed; consequently, the team could not provide the teachers with feedback related to classroom interaction. The feedback of the micro-teaching activities was shared with the teachers so that they could teach the CT-infused themes in their real classes well.

In real classroom teaching, the teachers implemented the CT-infused modules in their classes, with one team member sitting at the back of the class to observe the teaching process. So that different class levels, teachers and subjects could be observed within the available time, each team member sat in different classes to observe the teaching and learning process. All in all, 11 (eleven) classes were observed. The following table summarizes the classes observed during the real implementation of the developed CT-infused modules.

Table 2. Classes observed in the implementation of the developed CT-infused modules

Observer	Level	Class	Subject	Theme/Topic	CT Principles
Team Member C	Playgroup	A	Thematic	Fruits (*Buah-buahan*)	Abstraction
	Kindergarten	B	Thematic	Plants (*Tanaman*)	Abstraction Pattern Recognition Algorithm

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	Primary grade 1	1	Indonesian (*Bahasa Indonesia*)	Hygiene and Health (*Kebersihan dan Kesehatan*)	Decomposition Algorithm Abstraction Pattern Recognition
	Primary grade 2	2	English (*Bahasa Inggris*)	Likes and Dislikes (*Suka dan Tidak Suka*)	Algorithm Abstraction Pattern Recognition
Team Member B	Primary grade 4	4A	Natural Sciences & Social Sciences (*Ilmu Pengetahuan Alam dan Sosial/IPAS*)	Substance Form and Its Changes (*Wujud Zat dan Perubahannya*)	Decomposition Algorithm Abstraction Pattern Recognition
	Primary grade 4	4A	Infomatics (*Informatika*)	Making Animation Using TupiTube (*Membuat Animasi Menggunakan* TupiTube)	Decomposition Algorithm Abstraction Pattern Recognition
	Primary grade 6	6	Social Science & Arts and Crafts (*Ilmu Pengetahuan Sosial dan Seni Budaya dan Prakarya/IPS dan SBdP*)	Unity in Diversity (*Persatuan dalam Perbedaan*)	Decomposition Algorithm Abstraction Pattern Recognition
	Primary grade 4	4B	Natural Sciences & Social Sciences (*Ilmu Pengetahuan Alam dan Sosial/IPAS*)	Substance Form and Its Changes (*Wujud Zat dan Perubahannya*)	Decomposition Algorithm Abstraction Pattern Recognition
Team Member A	Junior high school grade 7	7	Social Sciences (*Ilmu Pengetahuan Sosial*)	Understanding Locations Using Maps (*Pemahaman Lokasi melalui Peta*)	Decomposition Abstraction Algorithm Pattern Recognition
	Junior high school grade 8	8	Natural Sciences (*Ilmu Pengetahuan Alam*)	Food and Digestive System (*Makanan dan Sistem Pencernaan*)	Decomposition Algorithm Abstraction Pattern Recognition
	Junior high school grade 9	9	English (*Bahasa Inggris*)	Let's Eat Healthy Food (*Ayo Kita Makan Makanan yang Sehat*)	Decomposition Algorithm Abstraction Pattern Recognition

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The real-class implementation of the CT-infused modules indicates good practices as well as some practices that need improving. The findings of the implementation are classified into good practices and practices that need improving. The former implies that what the teachers did during the community service program is supposed to become a part of their and will be followed by other teachers; the latter indicates that what some teachers did could be further improved or refined to make it even more effective in supporting and enhancing education quality. They are further elaborated as follows:

The good practices:

a) Most teachers could properly integrate CT principles into the lessons. For example, in the class of Social Sciences, the teacher applied the decomposition and algorithm principles when explaining the learning objectives in the session. She mentioned the learning objectives and then encouraged the students to see the steps to achieve them. Further, she integrated the algorithm principle into the mind-mapping activity of her lesson.

b) Most teachers presented the lessons systematically and gave clear step-by-step instructions.
For example, in the Natural and Social Sciences (*IPAS*) class, applying the algorithm principle of CT, the teacher instructed the students to do the steps of the experiments, one at a time in accordance with the instructions given.

c) Some teachers ended their classes by asking the students to draw a moral message related to the topic/theme of the lessons. This implies that the abstraction principle of CT was implemented. For example, in a Social Sciences class, the teacher ended the class by asking her students to draw moral messages related to the lesson learned. Some students stated some moral messages, one of which was ‘Having tough challenges or deficiencies should not be a reason to give up.’

d) Discussing the topic of "Understanding Locations Using Maps" with the principles of CT, the teacher applied a systematic problem-solving approach to the subject. She started by breaking down the problem of understanding locations using maps into smaller components. She assigned the students to do mapping, route planning, and location-based services. After that, she asked the students to do abstraction by identifying the geographic features, including landforms and ecosystems. Given a map, the students analysed the different types of terrain, including hills, valleys, cliffs, beaches, rivers and canyons. Lastly, they discussed the locations by applying the algorithms and logic.

e) The principles of computational thinking were applied to understand and describe the processes of food digestion and the digestive system. The teacher explained how to break down the food digestion process into its constituent steps. She explained that digestion involves ingestion, mechanical breakdown (chewing), chemical breakdown (enzymatic digestion), absorption, and elimination. After dealing with decomposition, she identified patterns within the digestive system. She explained that the digestive system follows a specific order, with food travelling from the mouth to the oesophagus, then the stomach, small intestine, and large intestine. The next activity was focusing on the key components and their interactions. In the digestive system, abstraction might involve understanding the roles of organs like the stomach, liver, pancreas, and small intestine in breaking down and absorbing nutrients from food. After all, the teacher explained the step-by-step algorithms for each part of the digestive process.

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f) Teaching English speaking to grade 9 students of Junior High School, the teacher not only provided a list of English syntactical rules but also the contents of the topic "Let's Eat Healthy Food". The teacher asked the students some questions about meal planning (decomposition), prioritizing nutrients (abstraction), identifying unhealthy eating habits (Pattern Recognition), and meal preparation (algorithm). Meal planning included breaking down daily food intake into complex food and snacks. Prioritizing nutrients dealt with focusing on essential nutrients like fibre, protein, vitamins, and minerals, rather than specific foods. Identifying unhealthy eating habits required the students to recognize patterns of overeating, emotional eating, or consuming too much processed food. Concerning meal preparation, the teacher asked the students to create a step-by-step process for planning and preparing balanced meals.

g) Teaching the topic of 'Hygiene and Health' to grade 1 students of Primary School, first the teacher talked about environmental cleanliness with the principles of computational thinking. She started by stating environmental issues like waste. She led a brainstorm of words associated with waste. Then, she broke down the environmental problems caused by waste into smaller parts and encouraged the students to recognize patterns in the environmental issue by identifying commonalities in waste problems caused by human activities. She also asked the students to focus on the core aspects of the impact of littering on the school environment. In groups, the students were scaffolded with a step-by-step guide on how to classify wastes and put them in the proper waste baskets.

h) Still related to the topic of "Hygiene and Health", while incorporating computational thinking to be a fun and educational experience, the teacher ended the session by inviting the students to apply the proper algorithm of handwashing. She taught the children the importance of washing hands by breaking down the steps of hand washing into a proper sequence. She showed the order of actions like turning on the tap, applying soap, rubbing hands together, and rinsing.

i) Turning the teaching of "Plants" to kindergarten students to be a fun and educational experience, the teacher showed a picture of the sequence of the plant life cycle. Then by showing the pictures of plants at different stages, she explained the basic parts of the life cycle of a plant: seed, germination, growth, flowering, and fruit production. The last activity was asking the students to arrange the pictures in the correct sequence to demonstrate their understanding of the plant life cycle, which was applying the algorithm principle of CT. The pupils were very enthusiastic in doing the activity.

j) Teaching English "Likes and Dislikes" to the students of grade 2 Primary School by incorporating the principles of CT is an effective and engaging way to help students develop language skills and think critically. The teacher started the class by discussing the concept of likes and dislikes in Indonesian. Then she introduced relevant vocabulary words, such as *like*, *love*, *enjoy*, *dislike*, *hate*, and *prefer* by using pictures to help students understand these words. She also gave examples of sentences such as "*I like ice cream*" or "*I don't like broccoli*." After that, she asked the students create and conduct surveys with questions like "*Do you like pizza or hamburgers?*" To encourage students to explain why they liked or disliked something, she asked them open-ended questions like "*Why do you like playing soccer?*" or "*What don't you like about rainy days?*"

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The practices that need improving:

a) Some instructions given to the students did not seem to give a really clear message. For example, in another IPAS class, the teacher said to her students, '*Isi wadah dengan air, tapi jangan banyak-banyak.*' (translated into English 'Fill the container with water, but don't fill it with much water'). Different students had their own interpretation of the amount of water poured in their containers. This message could have been made clearer if the teacher had said," Fill half of the container with water", or "Pour water into the container reaching half of it", or even used a picture of a container showing the level of water in it.
b) Some teachers should have implicitly shown how something could be done more effectively. For example, in an *IPAS* class, when the class session was about to end, the teacher asked the students to throw the water into the gutter, but she seemed not to give clear guidance to the students, resulting some water was sprinkled on the floor. The teacher could have demonstrated how to do it more practically and safely. Instead of using glasses to throw the water, it could have been placed in a bigger container to prevent it from spilling. With this demonstration, the class activities could also develop students' computational, problem-solving, and life skills.
c) Some teachers did not seem to fully apply the four principles of computational thinking in their classes. Lack of practice in infusing the CT principles into the lessons or lack of deep understanding of the CT concept and its principles might be the cause. Besides, having to adhere to the prescribed curricula and having limited abilities to integrate the four principles of CT into their teaching, they might feel pressured to focus on planning the activities for the topic taught. They felt uncertain about how to adapt their teaching methods to incorporate these principles effectively It seemed that integrating CT principles into teaching was still challenging for these teachers.
d) One kindergarten teacher did not seem to understand how to convey the concept of logical thinking to young children. For example, when choosing activities for the topic of "Plants", with *Carrot* as the sub-topic, the teacher asked the students to sew a picture of a carrot, which was not very relevant to the real-life experience. It is better to choose another more suitable activity for children, for example, coloring a picture of a carrot or shaping a carrot using playdough would be more suitable.

Conclusion

Based on the community service project's activities and the observed outcomes, the following conclusions are made:

1) The goal of this Government-funded community service program in assisting the teachers of Yohanes Gabriel Foundation sub-District Tuban to develop learning CT-infused modules and to implement them in real classroom teaching to some extent has been achieved.
2) Teaching is indeed an art; this implies that the more practice a teacher has, the better his/her teaching skills will be. The more effort he/she uses to integrate CT principles into his/her teaching modules, the better and more skilful he/she will be in infusing the CT principles into his/her lessons.
3) Developing and implementing learning modules infused with CT principles has positively impacted the participating teachers. The results indicate that the teachers have become more familiar with the principles of CT, and they have also successfully integrated these principles into the school's learning modules to some extent.

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4) Overall, these conclusions suggest that the community service project has effectively supported the professional development of the teachers, and empowered them to enhance the quality of education by incorporating computational thinking into their teaching methods.

Recommendation

The team recommends the following things for future community service involving CT in Education:

1) Maintaining collaboration with the school foundation, schools, and teachers
   To ensure the success of future community service projects involving computational thinking in education, the team needs to establish strong and ongoing collaborations with the School Foundation of Yohanes Gabriel sub-District Tuban, the respective schools and teachers. To do this, the team needs to explore their needs and align community service activities.
2) Creating tailored modules
   Future community service needs to conduct a thorough needs assessment to identify the specific requirements of the schools and teachers involved. This is done to create tailored learning modules that address the unique challenges and opportunities within each educational setting. Although the three different levels of education (kindergarten, elementary, and junior high schools) apply the same curriculum, the MC, the age groups of students and the resources are different.
3) Continuing the program for teacher training and professional development
   Training and professional development for all teachers of the different school levels should be provided to familiarize them with computational thinking principles and to assist them in integrating them into their teaching methods. This will indirectly empower educators to effectively implement the modules and support students in developing these skills.
4) Increasing community engagement and awareness
   It is recommended to promote community engagement by organizing workshops, seminars, or information sessions to educate parents and the broader community about the benefits of computational thinking in education. Collaboration with the respective foundation, schools, and teachers is needed to increase awareness and support from the community to overcome resistance or scepticism.
5) Addressing barriers and challenges
   It is essential to anticipate potential barriers or problems that can influence the results of the community service project. Common challenges may include resistance to change among teachers, limited access to technology, or a lack of time in the curriculum for additional subjects. These challenges should be addressed by providing support, resources, and flexibility in the project design.

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