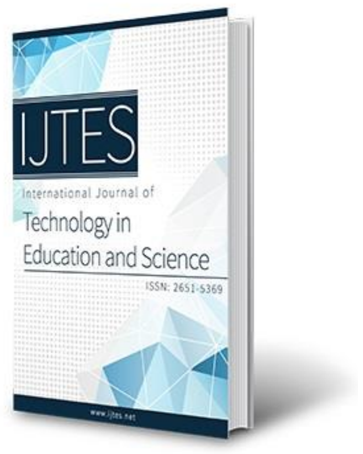

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Implementing Reflective Thinking in Computer Science Unplugged to Enhance Computational Thinking

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Implementing Reflective Thinking in Computer Science Unplugged to Enhance Computational Thinking

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Abstract

Facilitating Computer Science Unplugged (CS-unplugged) activities with reflective thinking activities lead students to in-depth reviews of their decisions and think of ways to solve the CS-unplugged problems. This study aims to evaluate the instruction enriched with reflective thinking activities to develop computational thinking skills. The study was carried out as a case study in a Computer Science course. The participants were 24, 5th-grade secondary school students. Students used two-column reflection notes and daily diaries to reflect their thoughts. Data were collected through Computational thinking skills evaluation form (CTEF), interviews, and observations to examine the role of reflective thinking activities during the instruction. Descriptive analysis, the thematic analysis was carried out through interviews was used to analyze data. The use of the two-column reflection notes and diaries positively contributed to the development of students' computational thinking skills. The students who engaged in reflective thinking activities outperformed in exhibiting their computational thinking skills than those who did not engage in. We hope that the findings of this study will assist in the future design and implementation of CS-unplugged activities to improve CT skills.

Introduction

Computational Thinking (CT) is crucial and stands out for anyone not just those involved in computer sciences (Weinberg, 2013). CT skills are posed among fundamental skills, alongside more conventional ones like literacy (Wing, 2006) and are considered as a reflection of various skills of the 21st century, such as algorithmic thinking, problem-solving, abstract thinking, creative thinking, and critical thinking (Basogain, Olabe, Olabe, Maiz, & Castaño, 2012). Researchers recommend examining the many approaches to issue resolution as well as the thought processes involved in these kinds of circumstances (Daher, & Anabousy, 2020). Studies address that CT is a high-level thinking skill in formulation of the problems which can be exhibited mostly by engaging in ill-structured problems (Aho, 2012) and CT topics can be taught at schools (Sanford, 2013; Voogt, Fisser, Good, Mishra and Yadav, 2015). Talan (2021) proposes examining the efficacy of pupils in a variety of other areas, including computational thinking abilities, problem-solving abilities, attitude, motivation, and anxiety levels.

In this sense, during the last decade, educators carried out several formal and informal instructions focusing on coding, educational games, robotics, interdisciplinary activities, and CS-unplugged activities to achieve these goals (Howland and Good, 2015; Kafai, Burke, and Resnick, 2014; Kazimoğlu, Kiernan, Bacon and Mackinnon, 2012). It is believed that CT skills can be taught through CS-unplugged activities led researchers to an increased emphasis on developing CT skills within CS-unplugged activities (Bell et al., 2009; Bischof, Mittermeir and Hodnigg, 2010; Gallenbacher, 2012).

CS-Unplugged Activities for Developing CT Skills

The CS-unplugged activities were used to support improving the students' perspectives towards computer sciences without actually using a computer (Taub, Ben-Ari, and Armoni, 2009). Gülbahar (2017) pointed out that techniques that provide the essentials of problem-solving through programming, as well as concepts such as variables, loops, and conditions, can be of use in CS-unplugged activities as well. By using CS-unplugged activities teachers physically introduce the internal dynamics of the problems to the students, and try to engage them as a part of the solution. Teachers can also facilitate group work and provide a learning environment by sharing ideas which leads to active learning (Cortina, 2015). On the other hand; CS-unplugged is generally suggested for students who are at the beginner level of CT skills or for whom it is difficult to deliver CT topics in other computer-based ways such as coding or robotics (Gülbahar, 2017).

CS-unplugged activities include a set of various games, puzzles, and pen-paper activities (Bell, Witten, and Fellows, 2015; Curzon, McOwan, Plant, and Meagher, 2014). Researchers argued that when properly designed, CS-unplugged activities can help the development of specific CT skills such as algorithmic thinking, decomposition, abstraction, logical thinking, generalization, and categorization step-by-step description of the solution, testing and debugging the solution, which are considered major sub-skills of CT (Brennan and Resnick, 2012; Csizmadia and Sentance, 2016; Gülbahar, 2017). Problem-solving involves steps of understanding the problem, planning a solution, implementing the plan, and monitoring and evaluating the solution (Polya, 1957; Jonassen, 2004). In understanding the problem phase, the patterns, and structure regarding understanding the problem (Akcaoglu, Jensen, & Gonzalez, 2021) and also in the following phases, CS-unplugged activities support problem-solving regarding CT skills.

In this context, some projects were implemented such as CSunplugged.org, CS4FN, Code.org unplugged, Informatik erLeben and Bebras (Demir and Seferoğlu, 2017; Leifheit, Jabs, Ninaus, Moeller and Ostermann, 2018; Oluk, 2017). One common feature of all these projects is that they help students discover the concepts of computer science while having fun, and foster the development of positive attitudes toward computer science and the use of CT skills through effective problem-solving (Oluk, 2017; NRC, 2010). Effective problem-solving requires students to provide reflections systematically (Wilson, Fernandez & Hadaway, 1993). At this point, Kizilkaya and Askar (2009) suggest to use of reflective thinking skills in problem problem-solving process. Researchers argue that learners who do not use reflective thinking skills during problem-solving may be unsuccessful in collecting necessary data, making plans for the solution, or searching for alternative solutions ways (Van Merrienboer, 1990).

Reflective Thinking in the Problem-Solving Process

Reflection is seen as one of the imperative elements of effective learning (Sugerman, Doherty, Garvey & Gass, 2000). Reflection can be considered as a link between learners ‘knowledge of the components affecting their learning, and learners' ability to use this knowledge in the learning process (Monteith, 2004). Thus, reflective thinking is considered as an opportunity to understand the positive and negative circumstances involved in problem-solving (Çubukçu, 2011; Epstein, 2003; Ünver, 2003). By reflective thinking, students may lead to review what they are doing in a given context and understand why a specific piece of knowledge is being learned.

With the help of reflective thinking activities in problem-solving, students can question assumptions, make inquiries, and come up with a summary of the issue, and comparisons (Çubukçu, 2011). On the other hand, reflective thinking encourages students to sustain their interest through the problem-solving process (Epstein, 2003). Effective problem-solving includes an effective planning phase, an actual solving phase, and an evaluation phase (Artzt & Armour-Thomas, 2001). Thus, reflections can be done before, during, and after problem-solving processes. After completing problem-solving tasks, reflective activities can provide feedback on evaluating the execution of the learning task (Ertmer & Newby, 1996; Spalding & Wilson, 2002). Based on previous experiences, these reflections allow students to orientate themselves for future problem-solving activities. According to Zimmerman (2000), self-reflection is the last phase of the cyclic process of self-regulation and it occurs after the completion of a learning activity and influences one's reaction to the experience (Zimmermann, 2000).

The Cs-unplugged activities which include ill-structured problems may lead students to reflect on problem solving. At this point; supporting the instructional process with reflective thinking activities may lead students to in-depth reviews of their decisions and think of the ways to solve the CS-unplugged problems. As in other contexts; with the nature of the CS-unplugged activities, students can identify their learning goals and feel responsible for learning, correct their mistakes, motivate themselves by noticing positive behaviors, and explain their opinions straight out. In the context of CS-unplugged activities; enabling students to organize and activate their thoughts may help students to develop their CT skills. When a student thinks deeply about what he/she did in the journey of problem-solving, his/her CT skills might be activated (Ünver, 2003; Wilson, & Jan, 1993).

Various researchers argue that reflective thinking can be improved through teaching (Kırnık, 2010; Kızılkaya and Aşkar, 2009; Tok, 2008; Yiğitel, 2015). Also, it is argued that reflective thinking activities embrace active perspective in the learning process by encouraging students to ask questions, explain existing assumptions, and summarize what is learned. Several strategies are suggested to support reflective thinking skills, such as utilizing learning texts, concept maps, open-ended questions, peer teaching, self-inquiry, self-evaluation, learning diaries, and portfolios (Wilson, &Jan, 1993).

The activities for enhancing CT skills often lead to the student's involvement in a problem-solving process, whereby they are assigned tasks to build up sub-skills of CT. As Kalelioğlu (2015) suggests effective practices may allow the student to step back to think of more useful reflective strategies for optimal solutions to the problems. This may also be realized as well as in CS-unplugged activities. To enable students to reflect on their ideas in the CS-unplugged activities, they can be supported by various tools or reflective thinking activities by teachers. In this context, this support is expected to develop the gains in terms of CT skills from CS-unplugged activities in particular given the nature of the problem-solving activities they involve. Reflective thinking during problem-solving in the CS-unplugged activities can help students assess and test the accuracy of the solutions. Thus, a need exists to investigate the effects of reflective thinking in the context of CS-unplugged activities to design programs to enhance CT skills further.

Aim of the Study

Supporting CS-unplugged activities with other activities to enhance reflective thinking is arguably helpful for achieving the learning outcomes expected concerning CT skills. The perspectives proposed in the present study, for the evaluation of CT skills through the whole process, rather than merely at the end of the process, can provide clues for improving the teaching designs for CS-unplugged activities.

The purpose of the present study is to investigate how using CS-unplugged activities enriched with reflective thinking activities affects 5th-grade secondary school students' CT skills. In this context, the research problem is formulated as “How reflective thinking activities embedded in CS-unplugged activities affect the computational thinking skills of the students?”

Methodology

The study is carried out as a case study including a set of endeavors to redefine or review a given case to reveal the underlying facts and generalizations involved in the case.

Participants

Participants were comprised of 24 students (10 girls and 14 boys) enrolled in 5th grade at a secondary school who took the Computer Science course in one semester. The course is newly incorporated into the curricula including CS-unplugged, block-based programming topics covered with CT skills. The students had adequate unplugged problem-solving experiences from the previous years, however, they did not face ill-structured problems that can be solved through pen-paper as in the implementation of this study. The study lasted 7 weeks, 2 hours per week.

Process

The course is carried out through 3 stages: introduction, application, and evaluation. In the introduction stage, the teacher presented the topics. In the application stage, the students were asked to work with two CT activities. After each activity, the students were asked to fill out a two-column reflection sheet. In the evaluation stage, the students were asked to write down the specific challenges they had when learning the topic taught, and how they overcame those challenges, in the “ITS Lesson Diary” kept within the framework of the activity to develop reflective thinking. To enable the use of CS-unplugged activities, the first step was to develop the course plans The step is seen in Figure 1. The activities to improve reflective thinking were integrated into the activities to improve CT skills through the curricula and the tasks were defined.

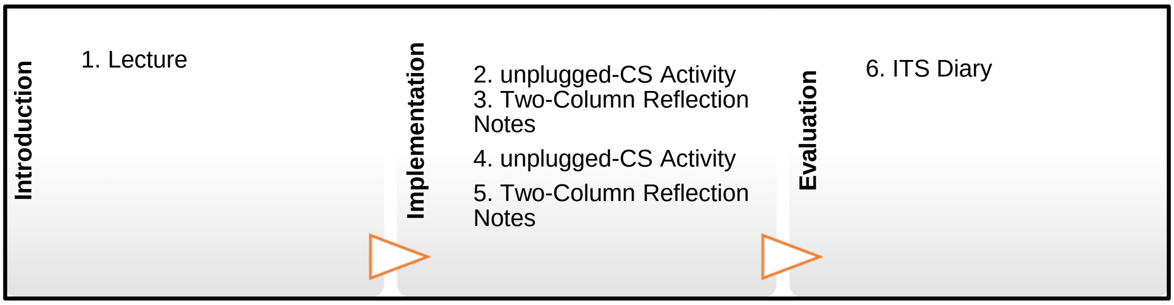

Figure 1. Course Plan (3, 5, 6: Activities to Improve Reflective Thinking)

In order to support students to engage in reflective thinking we used two main tools: Two Column Reflection Sheets and Diaries.

Two-Column Reflection Sheets

Reflection sheets arguably function as tools on which the learning achievements and failures of the students are recorded. The reflections can provide clues regarding the level of utility of each content element, the strengths as well as weaknesses of the processes involved, and the strategies employed in the learning process. Two-column reflection sheets cover the students' considerations regarding and their reactions toward the learning process. The reflections on these tools involve the students' notes on what they learned and the problems they came across through the process in one column of the reflections, and their remarks on their experiences regarding the learning process in the second column (Wilson & Jan, 1993).

Diaries

The students used the diaries to take note of their experiences concerning the knowledge they acquired during the teaching activities. Using the diaries, the students could transform what they have learned, and reorganize their knowledge. The content of the diaries was introduced to the students at the beginning of the course and they were asked to state what they faced during problem-solving, how they thought to solve the problems and how did they get support.

Data Collection Tools

The Computational Thinking Skills Evaluation Form (CTCE-F) was the main data collection tool in the study and it was used weekly to assess the CT skills concerning the activities. Observations and semi-structured interviews were employed to try and elucidate the relationship between reflective thinking activities and CT skills. Furthermore, the CS-unplugged activities and the CT sub-skills they involve are presented in Appendix 1.

CTCE-F: The form was developed by researchers concerning CT sub-skills identified for each activity by

Gülbahar (2017). Evaluation criteria for 14 activities and 9 sub-skills covered by such activities were specified (Appendix 2). While the students were working on the activities during the classes, the researchers observed the student's behaviors and took notes. The form was then filled out by the researchers, for each student, taking into account the CT sub-skills expected to be developed through the activity stipulated for a given week.

Observations: Throughout the process, the observations were carried out by the researchers. To do so, the researchers observed the students on an individual basis and without any intervention and kept notes of their observations. Interviews: Following the completion of the activities, semi-structured interviews were carried out with the students, individually. The data from TCRN and the diaries of the students were taken into account and interviews were carried out to explain this data. 9 students were selected through their CT scores and were asked the reasons for their behaviors in the tasks.

Data Analysis

The qualitative data gathered through the observations about the CT skills were scored through CTCE-F, and presented as graphs. The analysis was focused on the scores regarding the CT skills specified on CTCE-F, and presented with detailed descriptions, supported with data from other sources. While scoring CT skills, the CT sub-skill was defined in the task where the sub-task is exhibited. The scores of students in the sub-tasks were assigned through the evaluation criteria. As an example Week 1, Activity 2 is presented in Appendix 2.

The students' CT scores progress through the activities were presented on graphs, depicting the relationship between their reflections and CT, the nature of the activity performed, as well as the student's involvement in the reflecting thinking activity. The development of the students' CT skills was scored as follows: 3: advanced, 2: Sufficient, 1: Insufficient. In the analysis, the students were coded as S1, S2, S3..., S24. The analysis process is presented in Figure 2.

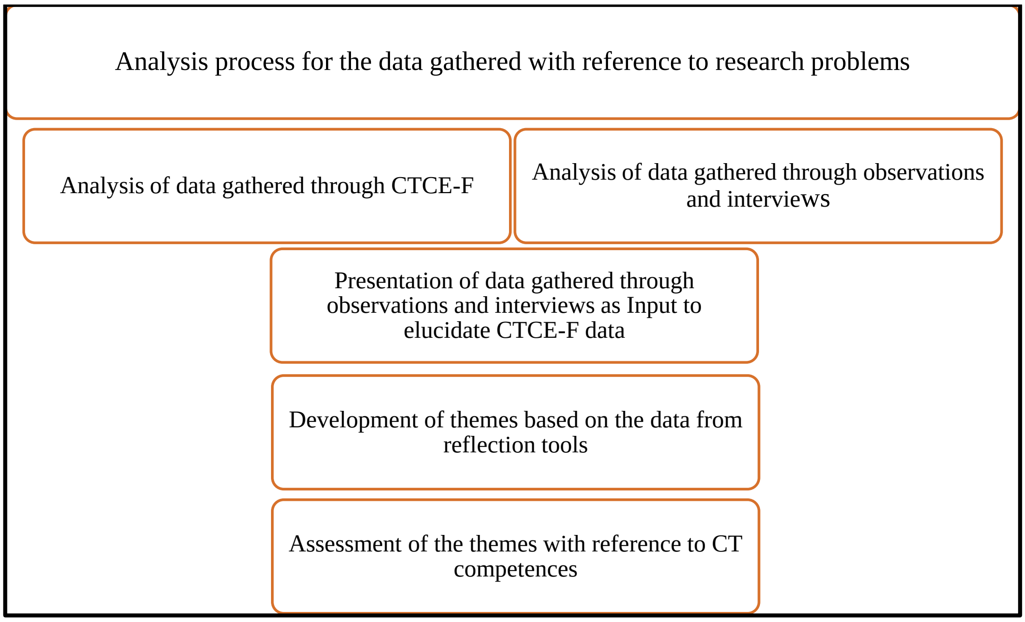

Figure 2. The Process for the Analysis of Data from Various Sources

Findings

14 activities were carried out in the study, 2 activities in a week in an unplugged setting over 7 weeks, supported with reflective thinking (two-column reflection notes, ITS diaries). Since the activities cover 9 sub-skills related to CT; the progress achieved by the students in terms of their CT was evaluated concerning groups comprised of such sub-skills. The groups of sub-skills were named algorithmic thinking and logical reasoning skills (Starting), coping with uncertainty, systematic thinking and identifying cause-and-effect relationships (Solution Process), abstraction, sorting, and generalization skills (Inference), and evaluation of the solution (Conclusion), concerning the order of the steps of problem-solving through the activities. Grouping as such made it easier to present the analyses regarding the sub-skills related to CT.

CTCE-F was used as the basis of the presentation of the findings. CTCE-F was employed concerning CT skills, to reveal the effect of reflective thinking activities to enrich the teaching process, on sub-skills involved. Using the form, first, two researchers analyzed the student's CT skills individually. Then, they discussed the scores together until they agreed on the scores. Inter-rater reliability coefficient between raters for CT skills was (K=0.87).

Development of Starting Sub Skills of Computational Thinking

The Starting CT sub-skills include algorithmic thinking and logical reasoning and are presented in Figure 3. The scores for individual sub-skills were assigned as Insufficient (<1.5), Sufficient (1.5 - 2.5), or advanced (>2.5).

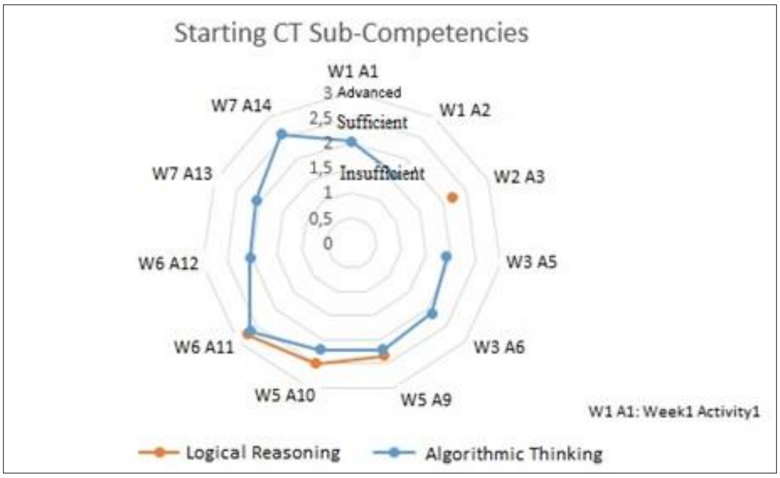

Figure 3. Development of Starting CT Sub-Skills

The algorithmic thinking scores of the students were between 1.5 - 3 (Sufficient/advanced). In the case of activities A2: Tower of Hanoi and A5: Directions, the students' algorithmic thinking scores have usually been in the advanced range, reaching to the highest score with activity A11: Complexity Game. Concerning the activity A11: Complexity Game where the algorithmic thinking skill reached the highest score, a substantial number of the students stated in their TCRN entries that the Complexity Game had been rather simple and connected with daily life. Some students who received "Insufficient" scores for most activities, got "Sufficient" scores regarding the algorithmic thinking skill in the Complexity Game activity. For instance; S10's TCRN entry regarding this activity is presented in Figure 4 and S7's notes in ITS diaries concerning the activity "What Should I Do Now" are presented in Figure 5 as an example.

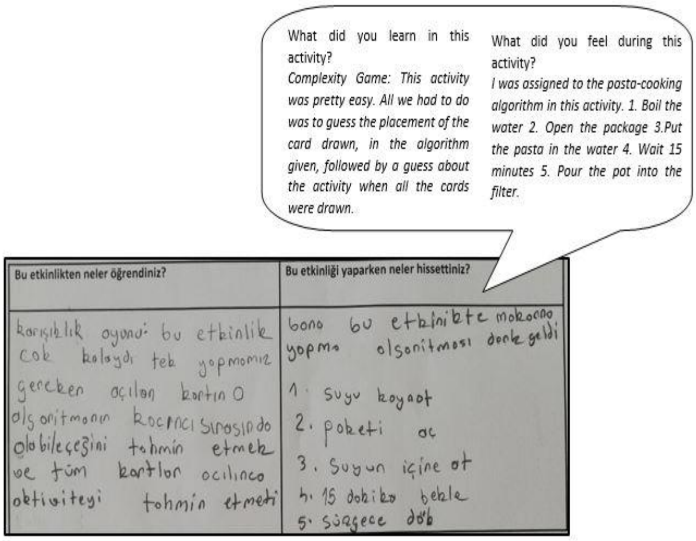

Figure 5. S7's diary entry for A3: What Should I Do Now

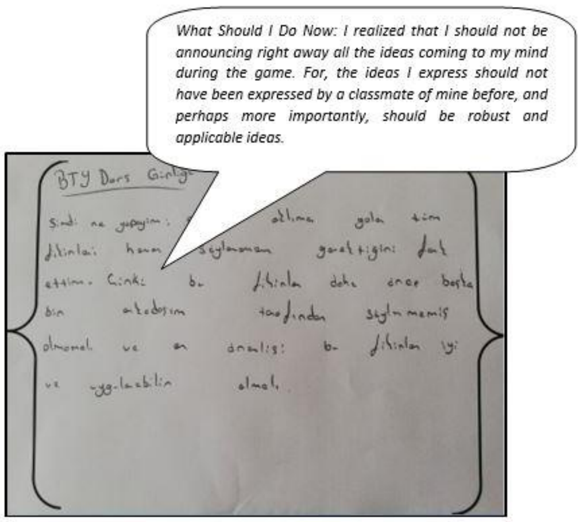

Figure 4. S10's TCRN entry regarding A11: Complexity Game

On the other hand, students' perspectives who received lower algorithmic thinking scores in some activities suggest that they had difficulty in keeping up with the steps of the activity. The logical reasoning sub-skills were analyzed through four distinct activities throughout the process, with students scoring an average of 2-3 (Sufficient/advanced) regarding this sub-skills. The average logical reasoning score for A3: What Should I Do Now rose gradually through activities E9: Estimation, A10: Go Figure, and A11: Complexity Game, maxing out at 2.75 with the last one. The TCRN entries and ITS diaries of the students who complete the tasks in the activities where the logical reasoning skill is analyzed suggest an inherent awareness of the need to develop the students' thinking along the lines of a certain way of reasoning. The average scores in algorithmic thinking and logical reasoning were calculated to express the impact of their performance in reflective thinking activities on the development of student's skills.

Table 1 indicates that most of the students' algorithmic thinking and logical reasoning are deemed to be well advanced, whereas the number of students whose reflections on their TCRN sheets and ITS diary notes scored higher is more than those who scored lower. The majority of the students achieved Sufficient scores for their logical reasoning scores. One can argue that using TCRN sheets contributes to starting skills, even if at a limited level. One reason why these sheets did not make substantial contributions in the case of students whose algorithmic thinking sub-skills were found to be Insufficient is that they cover unrelated details when using these sheets.

Table 1. Relationship between the Scores of Algorithmic Thinking and Logical Reasoning Scores and Reflection Performance

CT Skills		Reflection Performance					
		TCRN Scores			ITS Diary Scores		
		Advanced (f)	Sufficient (f)	Insufficient (f)	Advanced (f)	Sufficient (f)	Insufficient (f)
Algorithmic thinking	Advanced	6	3	-	5	4	-
	Sufficient	2	5	2	2	4	3
	Insufficient	-	-	6	-	1	5
Logical Reasoning	Advanced	13	3	-	5	7	4
	Sufficient	-	4	1	-	-	5
	Insufficient	-	2	1	-	-	3

The review of the statements entered in TCRN and ITS diaries by some students reveals that their TCRN scores could still be lower even if their algorithmic thinking sub-skills scores are higher. This is observed with a few students, while the majority of the students exhibited a linear correlation between their algorithmic thinking scores and TCRN scores. No significant relationship was observed between the students' algorithmic thinking scores and the scores derived from their ITS diaries regarding those sub-skills. Most students are observed to have relatively lower ITS diary scores compared to their algorithmic thinking sub-skills scores. These students could not provide the relevant statements in their ITS diaries despite the robust development of algorithmic thinking, and that, instead their reflections did not directly focus on the activity at times, and lacked concrete statements regarding reflective thinking at others. Moreover, some students' algorithmic thinking scores were found to be low, and coupled with even lower scores for their ITS diaries.

The students who scored high in terms of their logical reasoning also scored high with their TCRN notes, whereas the students whose scores for that skill were low also scored low with their TCRN notes. In the same vein, an analysis of the students' average scores for their TCRN notes and their ITS diary scores reveals that, except two, all students' ITS diary scores were lower compared to their logical reasoning skills scores. This observation suggests that, with few exceptions, the students who scored high in terms of their logical reasoning skills had been unable to engage in adequate reflection through their ITS diaries, despite their satisfactory scores regarding those skills. Figure 6 presents a part of the worksheet of S17, whose algorithmic thinking and logical reasoning scores were both “Sufficient”.

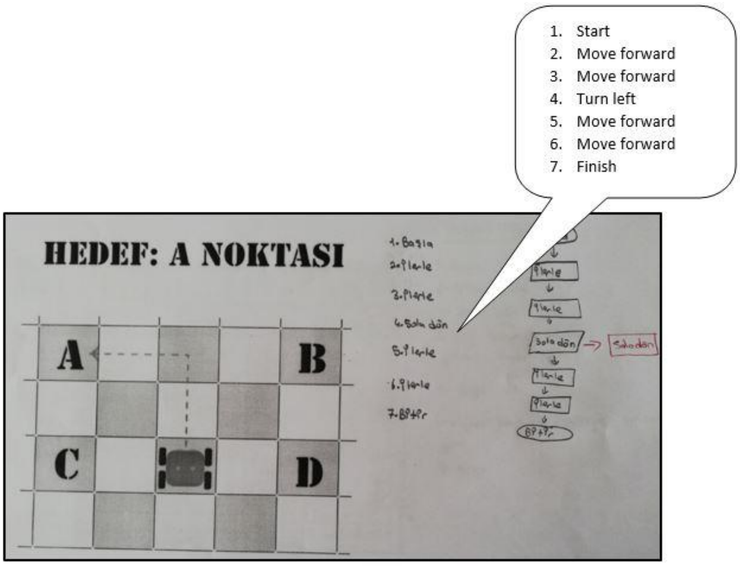

Figure 6. S17’s Work on Activity A14: Robot’s Route.

In sum, a glance at all activities covered by the study reveals that the students whose TCRN sheets and ITS diary scores were high also scored high in terms of algorithmic thinking and logical reasoning.

Development of Solution Process Computational Thinking Sub-Skills

The development of the solution process sub-skills including coping with uncertainty, systematic thinking, and identifying cause-and-effect relationships is depicted in Figure 7.

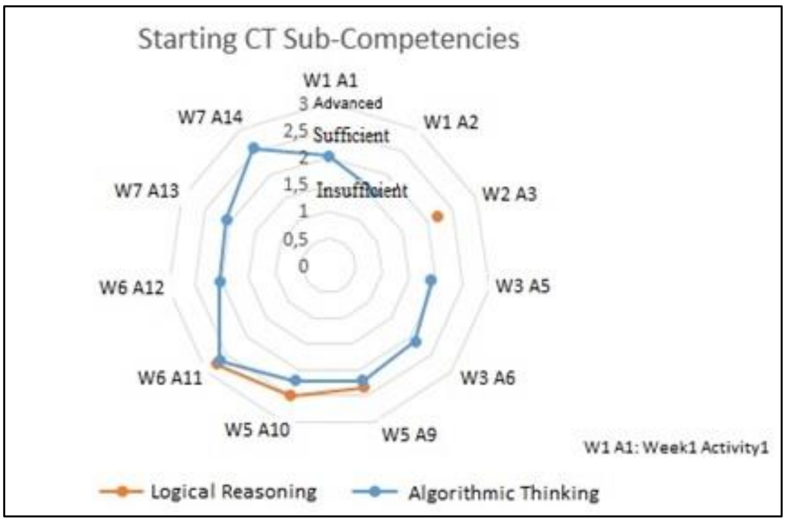

Figure 7. Development of Solution Process CT Sub-Skills

Figure 7 reveals that the average score of systematic thinking skills, which can be observed through the A3: What Should I Do Now activity was Sufficient (2.08). In this context, S2 expressed in her two reflection sheets with the statement "To get a higher score in this game I kept track of the ideas I came up with, to see if they were voiced before or not", noting how she began to take previous statements into account.The average score for the identifying cause-and-effect relationships skills was also found to be Sufficient (2.2). In the A4: Water Pollution activity covering this skill, several students, albeit small, were observed to fail in exhibiting the skill. At this point, the statements of the students S13, S14, and S20 present that they were unable to notice the causes they investigated concerning a given problem. In S13's words, this observation took the form of "When I was making a fishbone, I was unable to discern the relationship between the head and bones of the fish."

The average score for coping with uncertainty sub-skill was Sufficient (2 - 2.25). In A2: Tower of Hanoi the score for coping with uncertainty was 2.2, only to fall to 2 for A4: Water Pollution activity, and then rise to its highest level in activity A5: Directions with 2.25. Having fulfilled the assigned tasks in that activity, S6 stated in her TCRN and ITS diaries "When I saw the Directions activity for the first time, I thought it was a simple one. When I had some difficulty, I calmly put myself in the robot's shoes and continued my progress." The average scores concerning each Solution Process CT sub-skill and their performance while engaging in the reflective thinking activities were presented in Table 2.

Table 2. The Relationship between the Students' Solution Process CT Sub-Skills and Reflection Performances

CT Skills		Reflection Performance					
		TCRN Scores			ITS Diary Scores		
		Advanced (f)	Sufficient (f)	Insufficient (f)	Advanced (f)	Sufficient (f)	Insufficient (f)
Coping with Uncertainty	Advanced	5	3	-	4	3	-
	Sufficient	3	3	7	3	3	7
	Insufficient	-	-	3	-	-	4
Systematic Thinking	Advanced	8	2	-	5	4	1
	Sufficient	3	3	-	1	2	3
	Insufficient	-	4	4	-	-	8
Identifying Cause-and-Effect Relationships	Advanced	8	2	1	6	4	1
	Sufficient	-	3	4	-	2	5
	Insufficient	-	-	6	-	-	6

(f): The number of students who got the score.

Table 2 presents that the majority of the students scored in the "Sufficient" or "advanced" in these three sub-skills. The average score of a few students was "Insufficient". The CT Skills of the majority of the students who got advanced-level scores for all three sub-skills were also well developed. Even though a significant number of students received Insufficient scores concerning their reflections noted in ITS diaries, some still received Sufficient scores for their coping with uncertainty and systematic thinking sub-skills.

The analysis of the students' scores for coping with uncertainty, compared against their relevant TCRN scores, reveals that 16 students scored lower, compared to their scores for those sub-skills. Those 16 students include both those scoring high in coping with uncertainty, as well as those who scored low. These students were unable to express statements regarding these sub-skills in their TCRN reflections. The analysis of the relationship between the student's scores for coping with uncertainty and their ITS diary scores reveals that most students with a low ITS diary score had also scored low in coping with uncertainty. As an example; Figure 8 presents the TCRN reflection statements regarding A4: Water Pollution activity, by S23, who achieved significant progress regarding coping with uncertainty, systematic thinking, and identifying cause-and-effect relationships sub-skills and who achieved an "advanced" score for these sub-skills.

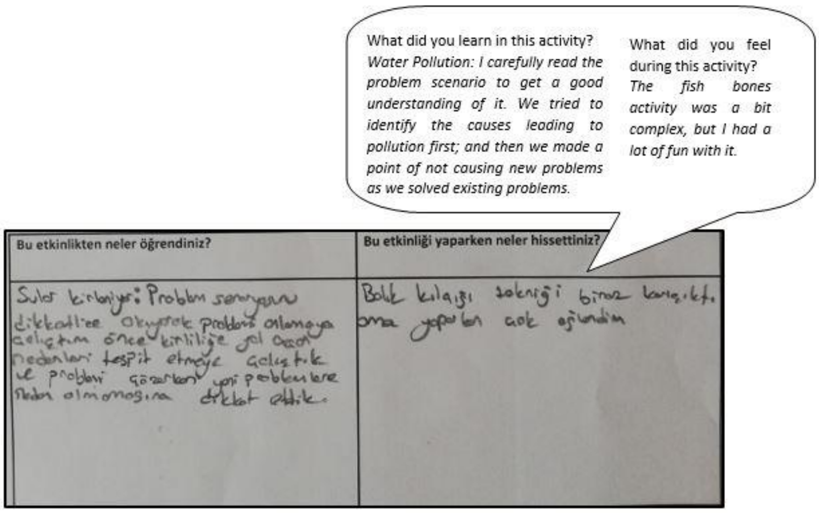

Figure 8. S23's TCRN Entry Regarding A4: Water Pollution

The students' systematic thinking scores and their TCRN scores reveal that the vast majority of the students exhibited a positive correlation between these scores. Only 2 students were found to get relatively low scores for their two reflection statements even though they scored higher for the systematic thinking sub-skill. The same 2 students were observed to omit statements regarding systematic thinking sub-skill in their ITS diaries. On the other hand, the students' ITS diary scores regarding the activities were generally low.

The students who scored high in identifying cause-and-effect relationships also scored high concerning their TCRN statements, while those who scored low in the former also scored low in the latter. This indicates that the use of TCRN reflections arguably helps with these skills. No change was observed in the ITS diary scores of 14 students, whereas their scores for identifying cause-and-effect relationships proceeded on a course comparable to their ITS diary scores.

In sum, one can infer that the students who made use of the TCRN notes and ITS diaries achieved significant progress in terms of their coping with uncertainty, systematic thinking, and identifying cause-and-effect relationships sub-skills, whereas the students who were unable to come up with significant reflections did not achieve progress concerning these sub-skills.

Development of Inference Computational Thinking Sub-Skills

Figure 9 presents the development of the Inference CT Skills entailing abstraction, sorting, and generalization sub-skills.

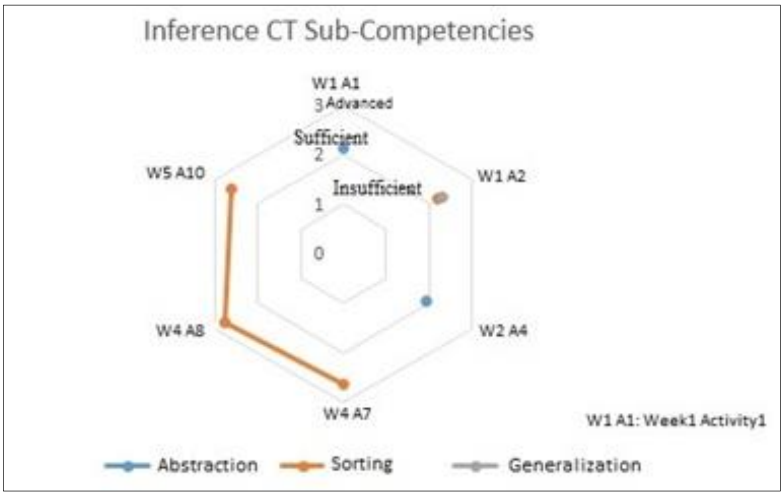

Figure 9. Development of Inference CT Sub-Skills

For the abstraction sub-skill, even though a wide range of scores were attained in different activities, in general, the scores for that sub-skill were in the "Sufficient" (1.5-2.5) level. For instance, in A1: Wolf-Sheep-Grass activity the abstraction score was found to be 2.12, only to recede to 1.91 in A4: Water Pollution activity. Concerning the scores for the abstraction sub-skill revealed that, especially in the case of A4: Water Pollution activity, they were unable to identify the primary cause, and were unable to discern the relationship between the head and bones of the fish as they solved the problem.

The generalization sub-skill was scored Sufficient (2.29) only in the A2: Tower of Hanoi activity. Some students had difficulty in meeting the "Capable of using the strategies developed as the student previously completed the game with 2 and 3 rings, this time for an instance with 4 rings" requirement expected from the students in the context of this activity. S24 expressed this difficulty in her TCRN reflections "I got confused and mixed up my moves as we had to make more moves when playing with 4 rings."

The average score for the sorting sub-skill was in the Sufficient-advanced range (2 - 3). The score for the sorting skill was Sufficient (2.2) in activity A2: Tower of Hanoi, rising to advanced level (2.62) in activities A7: Data Collection and A10: Go Figure, topping out at the advanced level (2.75) in activity A8: Game Analysis. The statements of the students who scored rather low in sorting during the activities carried out suggest that they approach the problem as a whole without trying to divide it into smaller sections. In this context, as an example S20 expressed in TCRN reflections "Had I tried to understand and comprehend the concepts of constant and variable first, and only then analyzed the examples in this light during the game analysis activity, I would probably have a lower number of mistakes." The average scores concerning each Inference CT Sub-skills are shown in Table 3.

Table 3. The Relationship between the Students' Inference CT Sub-Skills and Reflection Performance

CT Skills		Reflection Performance					
		TCRN Scores			ITS Diary Scores		
		Advanced (f)	Sufficient (f)	Insufficient (f)	Sufficient (f)	Sufficient (f)	Insufficient (f)
Abstraction	Advanced	8	-	-	7	2	-
	Sufficient	1	4	6	-	6	4
	Insufficient	1	-	4	-	2	3
Sorting	Advanced	12	3	-	6	6	3
	Sufficient	-	4	5	-	4	5
	Insufficient	-	-	-	-	-	-
Generalization	Advanced	9	3	1	6	5	1
	Sufficient	1	4	2	1	3	3
	Insufficient	-	-	4	-	2	3

Table 3 reveals that 12 students in sorting sub-skill, 9 students in generalization sub-skill, and 8 students in abstraction sub-skill received advanced level scores concerning these sub-skills. One point that stands out is that 5 students who received Insufficient scores for their reflective thinking as presented in their ITS class journal entries, had received Sufficient scores for their sorting sub-skills. In general, the students who score high in terms of their abstraction also score high with their TCRN reflections, whereas the students whose scores for those skills are low also score low in reflection sheets. The students who score high with their ITS diary entries also score high in terms of their abstraction sub-skill, whereas the students who score low with their ITS class journal entries also score low in terms of their abstraction sub-skill.

The TCRN reflection sheet data reflect that almost all students were lower than their sorting scores. These students scored higher in sorting, while their TCRN reflection sheet scores were lower. These students were unable to express statements regarding these sub-skills in their TCRN learning logs, as expected. Students' sorting scores and their related ITS diary scores reveal some level of fall in all students' ITS diary scores, with some suffering from truly severe levels of falls.

The students who score high in terms of their generalization skill levels also score high with their TCRN reflections. Yet, some students' relatively high generalization sub-skill scores were coupled with lower scores for their ITS diary entries. Against this background, the remarks on this activity, by S3, who achieved "advanced" scores on average for her abstraction, sorting, and generalization sub-skills in all activities, were presented in Figure 10 as an example. Her statement from the TCRN reflections is particularly noteworthy: “Every problem has a solution. All we need to do is to apply the steps for the solution in the correct order. Doing so makes the problem easier.”

Figure 10. S3’s Statement Regarding Activity A1: Wolf, Sheep, Grass

In sum, one can argue that acting in reflective thinking activities had a positive impact on the development of the students' abstraction, sorting, and generalization sub-skills in the wider context of their CT skills.

Development of Conclusion Computational Thinking Sub-Skills

Figure 11 presents the development through the process, of the Conclusion CT Sub-Skill, namely evaluation of the solution.

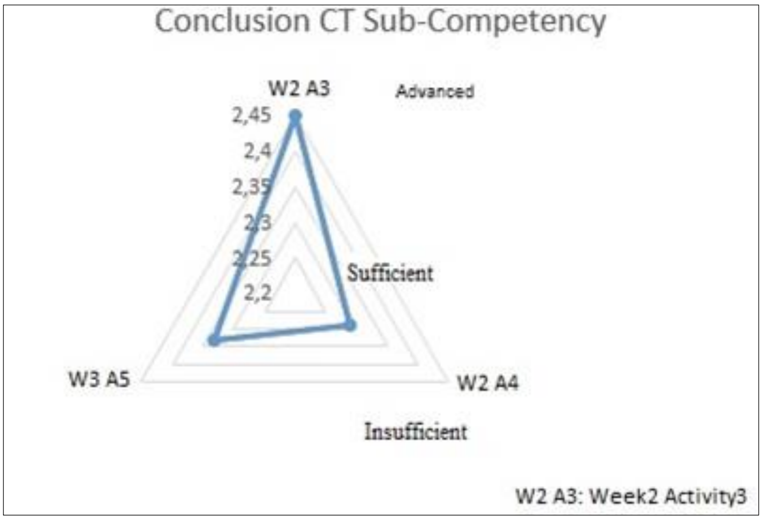

Figure 11. Development of Conclusion CT Sub-Skill

The review of Figure 11 reveals a “Sufficient” (2.25-2.5) progress level with this sub-skill. In activity A3: What Should I Do Now, the score for the evaluation of the solution sub-skill was 2.45, whereas in activity A4: Water Pollution it receded to 2.29, only to climb back to 2.33 in activity A5: Directions. The students’ statements regarding activity A3: What Should I Do Now, in which the highest scores for the evaluation of the solution sub-skill were achieved reveal that they noticed the steps to be taken for solving the problem, and became aware of the possibility to design different solutions. At this point; S4 stated that “During this game, all I had to do was to inquire about the views of my friends as well as my views. In other words, I had to decide if my view was applicable or not."

The student's evaluation of the solution skill scores was compared against their scores for their statements in TCRN reflection scores and ITS diaries to understand the progress of their scores through the process.

Table 4. The Relationship between the Students' Conclusion CT Sub-Skills and Reflective Thinking Skills

CT Skills		Reflection Performance					
		TCRN Scores			ITS Diary Scores		
		Advanced (f)	Sufficient (f)	Advanced (f)	Sufficient (f)	Sufficient (f)	Insufficient (f)
Evaluation of the Solution	Advanced	8	6	1	7	6	1
	Sufficient	-	-	5	-	2	4
	Insufficient	-	-	4	-	-	4

Table 4 reveals that the student's scores for their conclusion CT Sub-skills and their TCRN reflections and ITS diaries were usually in the advanced or Sufficient levels. It is noteworthy that a significant number of students whose reflective thinking activities were assessed as Sufficient scores had also received advanced scores for the evaluation of the solution sub-skill.The students who got high scores regarding the evaluation of the solution sub-skill also received high scores for their TCRN entries. While the evaluation of the solution sub-skill scores of some students was high, their scores for their TCRN entries were nonetheless in the "Insufficient" level. The students whose scores for the evaluation were low also had low scores for their TCRN reflections. In parallel to the case with TCRN entry scores, the scores for ITS diaries were also low along with the scores for the evaluation. On the other hand, it is understood that these students had improvements in their evaluation of the solution sub-skills, but were unable to include relevant statements in their ITS diaries.S19's TCRN notes regarding the Directions activity are presented in Figure 12.

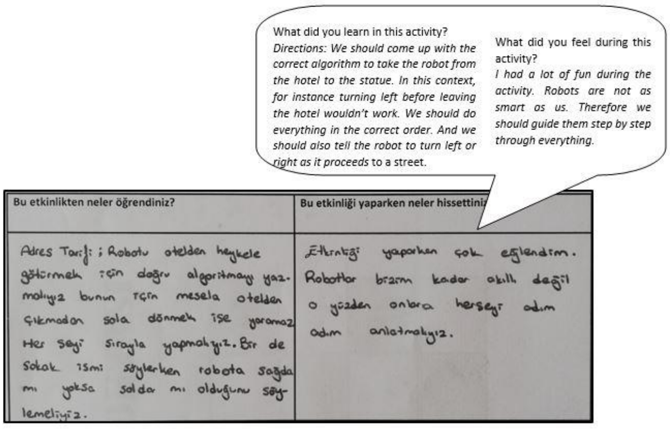

Figure 12. S19's TCRN entry regarding A5: Directions

To sum up, one can argue that the students with rather high TCRN scores also stand out with their high levels of evaluation. Thus, the use of the ITS diaries somewhat contributed to the development of the evaluation sub-skill. One can also note that the students who proved capable of reflective thinking through the process developed the skills listed below, at Sufficient or advanced levels.

- Getting acquainted with the fundamental concepts of and approaches to problem-solving.
- Developing solution proposals for the problems faced in daily life.
- Analyzing problems and defining the appropriate steps; coming up with solutions.
- Learning how to use the operators, expressions, and equations where required; understanding the importance of the priority and order of operations.
- Getting introduced to the algorithm concept, and developing algorithms for the solution of problems; noticing and fixing errors in existing algorithms.

The observations indicated that the contributions of students' actual evaluation of reflective thinking activities were presented on a thematic basis, concerning the statements the students made during the interviews as well. Moreover, these factors were addressed in the light of the students' expressions, culminating in inferences about the relationship between the use of reflective thinking tools and the CT sub-skills. Table 5 summarizes the students' use of tools for reflection, and the effects thereof on their specific sub-skills, in the light of TCRN and ITS diary entries.

Table 5. Factors Affecting the Students' Use of Tools for Reflection

Codes	Starting	Solution Process	Inference	Conclusion
Making entries concerning the activity	*		*	
Failure to focus directly on the activity	*	*	*	*
Ensuring lasting learning		*	*	
Getting stuck in unrelated details		*		
Spending extra time		*	*	
Willingness to keep track of the process		*		
Lacking confidence in their usability in real-life				*

Discussion

In this study where the role of reflective thinking activities in the development of CT skills in the context of CS-unplugged activities was analyzed, it is evident that the students perceived the activities employed for reflections in different ways. Some expressed a more emphasized interest in reflections during the earlier weeks of the process, allowing them to engage in reflective thinking and make relevant statements as expected. However, the interest in the reflective thinking activities waned gradually through the process.

Some students voiced the need for extra time and effort as an excuse for their refrain from the use of the correct tools for reflection and provided examples of delving into irrelevant details whenever they wrote entries. Some others, in turn, exhibited gradually rising interest levels. These students considered the reflective thinking activities as an essential element of the course and were eventually convinced that these activities would contribute to learning, as they came to see the positive effects of reflective thinking on their learning process. On the other hand, one can argue that the use of TCRN sheets and ITS diaries through the process contributed to the development of CT sub-skills (algorithmic thinking, logical reasoning, coping with uncertainty, systematic thinking, identifying cause-and-effect relationships, abstraction, sorting, generalization, evaluation of the solution), and therefore to the development of CT skill overall.

Researchers believe that students are equipped for the rapidly evolving field of computer science, and they recommend new strategies for teachers to improve their abilities. (Paek, Leong, Johnson, & Moore, 2021). In this sense, several studies claimed that unplugged activities can help the development of specific skills of dividing the solution into several smaller problems, abstraction, step-by-step description of the solution, testing and debugging the solution, which are considered major elements of CT (Brennan and Resnick, 2012; Curzon et al., 2014; Gülbahar, 2017; Sentance and Csizmadia, 2016). In this context, the results indicated that CS-unplugged activities could help to develop CT skills, as an especially effective teaching method alternative for the students who are newly introduced to CS-unplugged activities. The results indicated that the use of TCRN notes and ITS diaries as reflective thinking activities helped the student why and how to go through the CS-unplugged activities, and what to take into account when solving the problems. As a result; through the process, the students who were able to engage in reflection and the ones unable to do so had exhibited different levels of CT sub-skills.

Supporting the CT skills training with reflective thinking activities, leading students to eager and in-depth reviews of their decisions, engaging in reasoning, embracing critical perspectives, and thinking about alternative methods for the solution of the problems were crucial factors in the further development of CT skills. The present study also provided clues as to the roles the reflective thinking activities could play in students’ activities, rather than their effect of directly contributing to the development of CT skills. In this context, the results indicated that the reflective thinking activities' function of showing the student what to take into account when solving problems, and thus making better use of the potential offered by unplugged activities.

The scoring employed in this study helped to present the individual students’ progress through the activities, with the help of using graphs. CTCE-F was also particularly helpful in providing a detailed assessment of the progress. To date, activities to improve reflective thinking have been employed in numerous studies, to provide support for the students. The present study, in turn, showed the integration of reflective thinking activities into unplugged environments for the first time, achieving positive results by doing so. The natural compatibility of the reflective thinking activities with the characteristics of the domain (CS-unplugged) they were employed played a major role in achieving these positive results.

Overall, the findings confirmed the idea that the un-plugged activities have the potential to enhance CT and programming concepts. Additionally, Bell and Tracy Henderson's (2022) research has demonstrated that CS-unplugged is especially effective in introducing students to programming concepts and algorithms before their computer implementation.

Conclusion and Recommendations

In the study, the effect of reflective thinking activities in the context of unplugged CS activities, on the development of CT skills were examined and the following conclusions were drawn:

- The starting CT sub-skills; algorithmic thinking and logical reasoning were developed at a Sufficient level through the process. The students who scored high with their ITS diaries and two-column reflection notes also scored high at this point; using reflective thinking activities had a positive effect on the development of these skills.
- The solution process CT sub-skills were exhibited around the "Sufficient" level through the process. That is to say; the two-column reflection notes and ITS diaries significantly contributed to students' coping with uncertainty, systematic thinking, and identifying cause-and-effect relationships sub-skills, whereas the students who were unable to come up with significant reflections did not achieve progress concerning these sub-skill.
- The inference CT sub-skills also showed "Sufficient" levels of development through the process. Thus, the development of students' abstraction, sorting, and generalization skills was positively influenced by the reflective thinking activities.
- The evaluation of the solution as a conclusion CT sub-skill was also "Sufficient" throughout the process. The use of the ITS diaries mostly contributed to the development of this skill.

To conclude; the results suggest that; the students who filled out the reflective thinking in line with the requirements of the activity helped them to achieve progress with their CT skills as well. On the other hand, the use of reflective thinking activities had also some partly negative effects on the learning process. While engaged in reflection using these activities, some students were witness to lose their focus in the activity, and reflected on their feelings at that moment, rather than on the topics covered in the class. Furthermore, the fact that the reflective thinking activities were used during the class led to their perception as a waste of time for some students. Further comprehensive studies on various concepts associated with CT, involving CS-unplugged activities and activities to improve reflective thinking are in order. We believe our findings provide fresh insights on and new possibilities for instructional use of reflective thinking activities in CS education.

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Appendix 1. The Unplugged CS Activities and Included CT Sub-skills

Week	Act. No.	Name	Ct Sub-Skills
1	1	Wolf, Sheep, Grass	Abstraction Algorithmic Thinking
	2	Hanoi Tower	Coping with Uncertainty Algorithmic Thinking Sorting Generalization
2	3	What Should I Do Now	Logical Reasoning Systematic Thinking Evaluation of the Solution
	4	Water Pollution	Cause-and-Effect Relationship Abstraction Coping with Uncertainty Evaluation of the Solution
3	5	Directions	Coping with Uncertainty Evaluation of the Solution Algorithmic Thinking
	6	Listen and Draw	Algorithmic Thinking
4	7	Data Collection	Sorting
	8	Game Analysis	Sorting
5	9	Estimation	Algorithmic Thinking Logical Reasoning
	10	Go Figure	Algorithmic Thinking Logical Reasoning Sorting
6	11	Complexity Game	Algorithmic Thinking Logical Reasoning
	12	Tortop’s If-Else Experience	Algorithmic Thinking
7	13	Thirsty Pussycat	Algorithmic Thinking
	14	Robot’s Route	Algorithmic Thinking

Activity 2. Activity Assessment Criteria

Week 1, Activity 2: Hanoi Tower

Algorithmic Thinking	
Score	Criteria
1	Does not see the connection between the rings as well as the rules of the game, and is unable to develop an algorithm.
2	Develops an algorithm through trial and error. Takes a longer route even though the requirement expects the optimal number of moves.
3	Develops the algorithm correctly, to achieve the transition through the lowest number of moves. Moves just 1 ring with each move. Does not cover a ring with a larger one. Moves the rings from column 1 to 3, to exhibit the same shape.

Generalization	
Score	Criteria
1	Is unable to establish a connection between old and new information.
2	Can use previous knowledge when playing the game, but completes the game with a higher-than-optimal number of moves.
3	Capable of using the strategies developed as the student previously completed the game with 2 and 3 rings, this time for an instance with 4 rings.

Coping with Uncertainty	
Score	Criteria
1	Feels bias in the form of attaching undue difficulty to the game, and worries about potential failure to find a solution.
2	Develops distinct strategies for the solution, but is unable to estimate the results of the subsequent moves.
3	Is able to understand the input and requirements of the game. Thinks about the subsequent results of the moves down the line, and acts accordingly.

Sorting	
Score	Criteria
1	Do not attempt to break down the problem into smaller pieces, or to take a look at previous solutions.
2	Tries to make the right moves by repeating a previous solution involving a smaller number of rings, but does not try taking notes so as not to lose her way.
3	Uses pen and paper to keep track of the previous and next move during the solution. Refers back to the solutions developed for 2 or 3 rings to develop the optimal strategy when working with 4 rings.