Programming education in Japanese schools Identification of existing barriers and suggestions for the teacher's online platform

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Abstract: Educational system and policy keeps reforming itself reflecting the needs of the society. In 2021, the new educational standard came into effect in Japanese education and "programming education" became compulsory in elementary schools. The "programming education" is to enhance what was explained by the Ministry of Education as "programming-like education," which concepts were developed based on those of Computational Thinking. But changes always bring challenges. Even with the attempt led by the government in supporting the educators, many schools and teachers are currently far from prepared to facilitate programming education. This paper tries to point out the factors preventing an effective implementation of programming education in the Japanese context, and suggests as a solution development of an online platform for educators introducing example functions that would reinforce the materialistic, technological and psychological weaknesses identified.

Key-words: programming education, Computational Thinking, online platform

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1 Introduction

1.1 Education system adapting to outcomes of industrial revolutions

It often helps to understand the backgrounds of the change we are about to face when we discuss them from a larger scope. In 2021, the new Course of Study (an outline standard of the elementary and secondary school curricula) came into effect in Japanese primary schools, and will in secondary schools in the following years. One of its most remarkable changes is the introduction of “programming education” whose intentions will be discussed later, and Japanese schools are now challenged to handle this new concept in their practice. Obviously, it is not the first technological revolution in the educational sector the country or the world has seen, but on the contrary, it has experienced several major transformations as society and technology advanced with the times. Thus, I would like to start by overviewing how education has been adapted to the change in societies, especially the results of several stages of industrial revolutions.

The globally prevailing school system where students receive instructions divided according to student’s age and subject matter within a specific time frame was introduced mostly in the late 19th century when the society faced the need to create citizens who worked in conformity as the economy expanded through industrial revolution. Since then, the world has seen further industrial advance followed by educational adaptation. Halpin & Walsh [1] cites the description by Mathews, Hall and Smith (1988) on the transformation from the 20th to 21st century as follows: “The industrial system that has dominated the twentieth century - a system based upon mass production, mass consumption, Taylorised fragmentation of work and deskilling - is visibly dying. [...] A new industrial system is being born - based upon technologies of microelectronics and new materials, intelligent production, human-centered organization, worker responsibility and multi-skilling.” Today, in the midst of the fourth revolution characterized by automation of manufacturing using technologies such as machine-to-machine communication and the internet of things, the education curriculum must be able to direct and shape students ready to face a more digitally advanced society with an emphasis on the fields of STEM [2].

1.2 History of educational transformation in Japan

When it comes to Japan, the modern education system was founded at the start of the Meiji Era, the first modern government established after the political revolution in 1868. The American-model three-level school system was introduced while the French-style administrative structure was adopted for the central body to ensure the new education system prevailed across the nation. Education became compulsory for all the children of elementary level for the first time, at least in regulation [3]. After the war, out of the need for industrialization of the nation in order to recover its economy and catch up with the victors, Japan enacted two laws aiming to promote education areas specific to science in 1951 and 1953. They allowed schools to apply for a national subsidy for setting up and improving their scientific facilities. The impact of these laws cannot be determined; however, it soon became an international understanding that the Japanese education was successful in producing a large number of people with certain qualities demanded by the industrial world which included, along with scientific skills and knowledge: disciplined, diligent, constant, and collaborative. Evidently these qualities could be formed through the culture of conformity which was repeatedly stressed in daily classroom instructions and school events.

However, the significance of conformity quality gradually faded as the world became more and more closely connected due to the internet and more people started to recognize the complexity of the issues shared among multiple nations or the whole world. PISA test in 2003 introduced in its domains for the first time "problem thinking skills" (PISA, 2004) which presumably influenced the subsequent Course of Study in 2008 to incorporate the idea of nourishing "abilities to think, judge and express" [4], the description still to be found in the current version of the course of study. It appears to evidence the recognition on the importance of soft skills, while not diminishing the focus on STEM subjects. The term "programming" has been included in the courses of study since the early 1990s, but it wasn't until 2008 that it was made compulsory for secondary education. Then, the following revision devised in 2017 incorporated "programming education" as part of compulsory education in primary level, which came into operation in April 2020.

2 Computational Thinking education in Japan

2.1 Start of "programing education" and its intention

In 2017, the Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT) announced a new Course of Study in which "programming education" became compulsory in primary education. MEXT [5] explains that it does not necessarily intend to teach children how to write codes with computer, but rather to have them realize that "computer technologies are being used in their everyday life" and "there are necessary procedures in order to solve problems," and mentions that such learning is to be pursued "through standard subject teaching." Thus, "programming education" is not to learn coding. Furthermore, programming education expects to nurture their "programming-like thinking," described as follows:

"Abilities to think logically about [a)] <u>what combinations of actions are required</u>, [b)] <u>how to combine symbols corresponding to each action</u>, and [c)] <u>how to improve the combination of symbols</u> in order to [d)] <u>realize a series of activities one intends or approximate the outcomes to one's intention</u>" (translated) [6].

This definition remarkably resembles that of *Computational Thinking* (CT). Since the term CT was first used by Seymour Papert in 1993 and coined by Jeannette Wing in 2016 [7], it has been defined on numerous occasions and became an integral part of STEAM education around the world.

Each underlined description corresponds to a skill commonly listed for definitions of CT as follows:

(a) Decomposition: Breaking down data, processes, or problems into smaller, manageable parts
(b) Abstraction: Making a problem more understandable by reducing unnecessary detail
(c) Algorithm Design: Developing the step-by-step instructions for solving this and similar problems
(d) Evaluation: Evaluating whether solution solves the problem efficiently

Although some of the components like pattern recognition or evaluation are not explicitly expressed, it is evident that the idea of "programming-like thinking" was shaped with CT components. Hence, in order to avoid further misunderstanding on the intentions of the "programming education," it will be mentioned as "CT education" in this document when it is used to describe its concept, and not the policy itself.

2.2 Environment setup for CT education – "GIGA School Program"

In order to prepare the school environment for realizing the programming education introduced in the new Course of Study, MEXT devised a nation-wide ICT environment promotion program. The “GIGA School Program” originally requested for several requirements to be achieved by the school year of 2023 (*) including:

- Supply one educational device (such as a tablet) for each student,
- Install a high-speed school-wide network, and
- Place ICT education supporters in schools [5].

* The achievement goal has been moved up to 2021 due to the pandemic demands.

However, the program was not well publicized. It was endorsed by the Cabinet in December 2019, but only 22.2% of school teachers knew about the program and 25% knew it but didn’t know what it was at the time of May the following year even though they were already facing the pandemic emergency [8].

2.3 “Programming Education Platform” by MEXT

There is an official online platform for CT education (mainly for primary school) predominantly run by MEXT (Fig. 1). The main content of the platform is to provide the activity ideas and methods to be implemented inside or outside of the classroom for educators. Other contents include brief introduction of educational tools such as Scratch and micro:bit, and events information related to CT education. It does not hold a lot of content yet, but it shows the intention to support school teachers in introducing CT education in their practice. The details of the platform will be also examined later in this paper.

Figure 1 : Online platform provided by MEXT (Source: MEXT)

2.4 In the field

Above were initiatives led by the government. Now, I would like to briefly mention the voices from the public. Mobile Marketing Data Labo. (MMD) reported that over 80% of primary students and over 70% of secondary students recognized the need of programming education, and even more proportion from each group wanted to learn it [9]. Mothers having a child of such age showed a similar expectation for their child.

A leading example of active use of ICT into classrooms is Ritsumeikan Primary School, a private school located in Kyoto City. The school envisioned an environment where each student would have a device as early as 2012, and their activity using Minecraft in which the students interact with other schools internationally is well regarded [10].

3 Barriers against implementation of CT education

The example of Ritsumeikan Primary School helps us draw a picture of an educational model other schools can follow. However, the situations of a private school such as Ritsumeikan can be often unique for the available resources, the structure of management, etc. Now I would like to point out existing barriers that public schools have, do, will face in terms of implementing CT-related activities. The aim is to explore the possibilities for CT education that can coexist with current challenges.

3.1 Lack of budget

Generally, the proportion of expenditure assigned for compulsory education is low in Japan. According to the OECD report in 2020 [11], Japanese government spent almost 8 percent of national expenditure on education which was the fifth lowest among 46 of OECD countries (pp.308). Less than 3 percent of GDP was being spent on non-tertiary education and this was the fourth lowest (pp. 287).

In addition, while it is internationally common that the central government provides the majority of initial funds for non-tertiary levels of education, it is the regional governments in Japan that are the predominant source of initial funds (pp. 313). This funding flow makes it easier to adapt to regional needs, while possibly causing wide regional gaps.

In fact, the financial challenges are not only for public schools to face. Private schools, granted only half the government subsidies compared to the public schools, were reported to be even more struggling to secure budgets to equip every student with a device in pursuance of the GIGA School Project. This is especially notable in rural areas where the number of students is decreasing [8].

3.2 Lack of facility

MEXT [5] conducted a survey on the installation status of GIGA School Project requirements targeting all the K-12 public schools and reported the following findings:

- The number of computers per student has only made a small progress for the last ten years. In March 2020, approx. 5 students on average had to share one educational computer in the school. Primary schools have the least with 0.18 computers per student, followed by lower secondary with 0.21 computers per student and upper secondary with 0.24 per student (Fig. 2).
- While more than 90 percent of school classrooms had wired internet connection installed, wireless internet connection was available in less than half the classrooms. However, the number has remarkably increased in the last five years (Fig. 3).

- 40 percent of the classrooms have neither a projector, digital TV, or electronic blackboard.

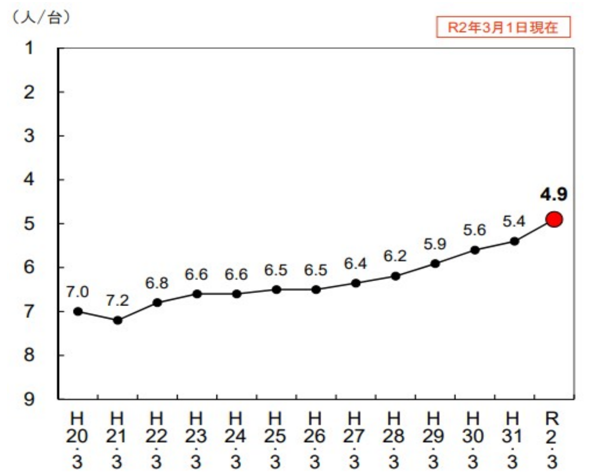


Figure 2 : Number of students per educational computer in public K-12 schools (Source: MEXT)

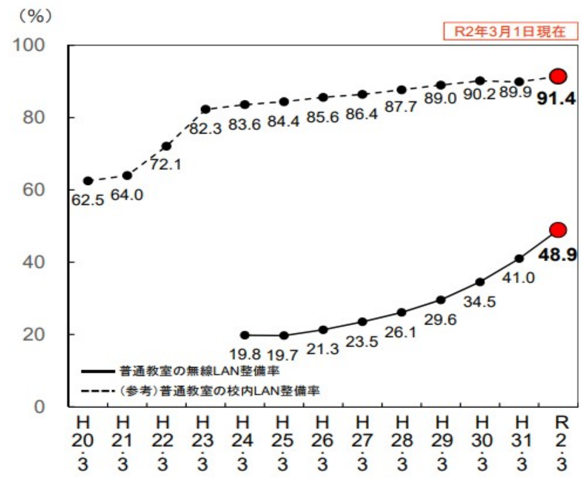


Figure 3 : Percentage of classrooms with internet connection installed, wired: dotted line / wireless: solid line (Source: MEXT)

3.3 Large-sized classroom

A large number of students for a teacher make it even harder to ensure high quality learning for every student. OECD [11] reported that only Chile, Israel, the UK and Japan had 25 or more students in an average primary classroom (pp. 371). In secondary level, the average class size was 30 to 35, while the OECD average was 23 (pp. 376). In such classroom settings with the limited capability of teachers to supervise and give feedback to the students, students' working in groups is essential in almost all stages so they maximize the possibility of students advising and assessing each other.

3.4 Lack of understanding and skills in teachers

Training teachers is a critical part of penetrating any educational reform in practice. Not only does otherwise the concept of CT education become a pie in the sky, but also we need to ensure qualitative equality in education throughout the nation. For that, teachers sharing the basic understanding and skills regarding their responsibilities is important.

The training MEXT offers for the teachers is limited to offering on its website support materials (documents) introducing several lesson plans to incorporate CT concepts using Scratch for primary school teachers as shown in Fig. 4. The rest is up to each municipality, school, and individual teachers. Some schools invite instructors from a private educational institution to organize training for the teachers.

Figure 4 : Support materials for primary schools provided by MEXT (Source: MEXT)

According to the survey of LINE Mirai Foundation [12], 73.3 percent of the primary school teachers feel worried about programming becoming part of the compulsory education, and 64.4 percent of them responded they were not confident in implementing it. Younger teachers (aged 20-34) were feeling the most anxious (Figure 5 : Anxiety about programming education among primary school teachers. It might be because of their insufficient teaching experience in general, but it is possible that older generations don’t feel much pressure to have to change their educational practice by the revision of the national curriculum due to lack of instructions for both implementation and evaluation of the programming education. This could be also a cause for 60.0 percent of the teachers stating that their school hasn’t set achievement goals of the programming education. However, it was also reported that almost one third of the respondents had experience in studying programming. The extent of study was unknown in this survey, but those who have experience felt less worried about programming education than those without it by 11 points.

Another important notion was mentioned by Sakamaki & Fukushima that an unignorable proportion of teachers actually doubted the educational effect of programming, placing it as the second largest concern about programming education raised by the respondent teachers, only after lack of knowledge and experience [13].

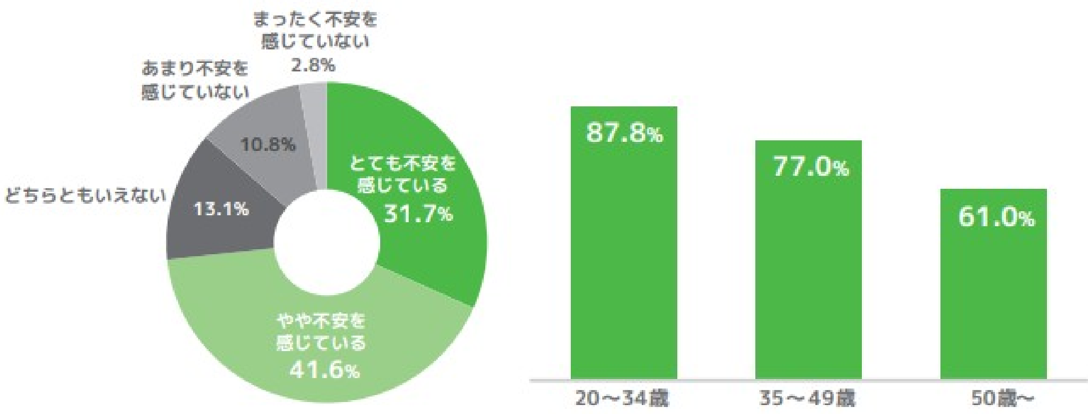


Figure 5 : Anxiety about programming education among primary school teachers
(Source: LINE Mirai Foundation, 2020)

4 Suggestions for online platforms as a resource center and connecting tool

4.1 Summary of challenges

Based on these barriers, the two concepts below should be taken into account in order to promote CT education.

- ***Tool***: The amount of budget as well as ICT environment differ among regions and schools. In order to make sure students in every school receive the same quality education, the resources should be almost or completely free and can be utilized in class without stable wireless internet connection, such as meaningful use of unplugged activities or tools that can be downloaded and operated offline.
- ***Objectives***: Currently, MEXT only provides the broad aim of CT education mentioned as the definition of “programming-like thinking.” Despite some efforts to provide example materials, the lack of concrete instructions makes it harder for teachers to determine goals for a set period and create a roadmap to achieve them. For example, ISTE provides a teacher resource with a progression chart of each component of CT by age group [14]. This one is too specialized in CT to be integrated into conventional subjects, but a learning path example like this would benefit individual teachers when they plan to incorporate programming in their teaching and also reflect their practice.
- ***Environment for teachers***: While most teachers are not confident in starting programming education, their problems vary. Some are simply overwhelmed by the new requirement on top of their lack of experience as a teacher, some are skeptical about the meaning of programming education in school, and even though it was not evidently stated, some might have difficulties using computers in the first place. To cover such wide-ranging concerns, an environment that accommodates co-learning/supporting of teachers needs to be set up.

4.2 Online resource center

One solution to tackle these challenges is an online resource center for teachers that offer them examples of activities/lessons and tools for planning, implementing and assessing their CT education. Table 1 shows some websites designed for Japanese teachers to search for lesson plans incorporating programming education.

Name of the website	Programming Education Platform	Procurri	Proanz	Computer Science for ALL
Operator / Institute	MEXT (in cooperation with other ministries)	Code for All	Benesse	CANVAS
Number of lesson plans* * As of June, 2021	< 50	< 30	< 30	< 60
Lesson plan search by grade	Yes	Yes	No	No
Lesson plan search by subject	Yes: currently there are only three subjects	Yes	No	No
Lesson plan indicating the corresponding unit objectives	Yes	Yes	Yes	No
Accept submission of lesson feedback from users	Yes: with required format	Yes: no required format	No	No
Accept submission of a lesson plan from users	No	No	No	YES: via inquiry form
Other features	It publishes news on programming-related events for students	Lessons are also searchable by tags such as the tool to use.	-	Apart from lessons, it has workshop ideas independent from the regular curriculum

4.3 Dispersed resources and lack of interaction

Apart from these examples, some public educational institutions set up by their city governments offer their own materials for CT education. Oita Prefectural Education Board, for example, publishes Can-Do charts of ICT-related competencies and example plans of how to integrate them into subject learning [15] while Tokyo Metropolitan School Personnel In-Service Training Center [16] provides guidelines for a holistic planning to promote CT education within a school. However, it's possible they don't have much visibility to teachers outside the region. In other words, the amount of resources teachers would have access to can depend on where they teach and whether they are informed. Given the so far insufficient contents and similar features in most of the resource centers in Table 1, integration of the resources might be a good step to take. That will save time for teachers to search for a lesson idea they are looking for, and if they want to share their original lessons, they know where to submit.

However, another issue with these resource centers is that they don't initiate nation-wide collaboration. Not only are the resources dispersed, but almost all the websites don't allow interaction of users. Importance of building a teacher's collaborative network via online tools has been mentioned many times [17], [18], and the necessity was even more strongly recognized through the pandemic period. Honigsfeld & Nordmeyer [19] point out that physical distancing is not to create isolation, on the contrary, to promote our sharing not only materials but experiences, both successes and failures, and thus contributes to the well-being of teachers. On top of the dawn of CT education, with almost every teacher facing the same challenge globally, a tool to connect them across the country and even internationally is something we must have.

In Japan, there has been a culture of lesson-based collaborative research where teachers from different schools examine and observe each other’s lesson plans and actual lessons for their professional growth [20]. In addition, SNS has spread across the nation’s generations for the last couple of years. More than 20 percent of the 60s use Facebook, while Twitter, though not very common among the older generations, is used by almost 70 percent of the 20s and around 40 percent of those in 30 to 50 [21]. With these in mind, there seems a good potential for an online community to enhance collaborative work among teachers.

4.4 Online platform as a connecting tool

When it comes to the form of online collaboration, there are some examples we can take from. In E.U., Erasmus+ offers an online teacher’s community eTwinning (Fig. 6), which allows teachers to find news and events, discuss a topic with other teachers, and also create a project together. It also works as an SNS and lets users connect with each other. Teacher 2 Teacher (Fig. 7) encourages teachers to engage in discussions or activity circles initiated by member teachers by listing their SNS posts on its website. It also offers a section of blog posts written by teachers which readers can comment on. The US-based Common Curriculum (Fig. 8) helps teachers not only create and share the state curriculum aligned lesson plans with templates but also organize the lesson schedule and track which curriculum standards have been covered. Teachers can collaborate in lesson planning in real time and comment on each other’s work.

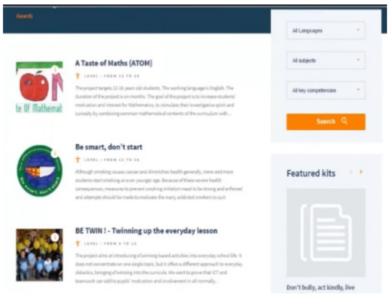


Figure 6 : Project search (Source: Erasmus+)

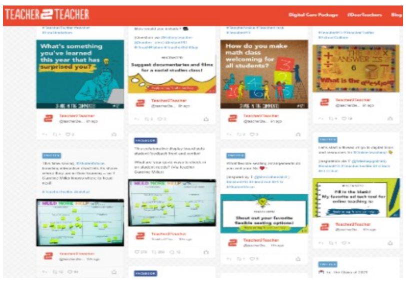


Figure 7: SNS posts with discussion topics on Teacher 2 Teacher (Source: Teacher 2 Teacher)

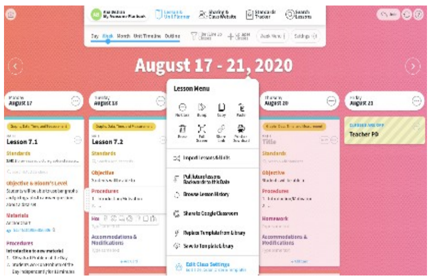


Figure 8 : Lesson management on Common Curriculum (Source: Common Sense Education)

These examples show that teachers learning from online interaction with each other is becoming a norm. One might find at least two aspects in which online collaboration helps teachers interact with each other: 1) the practical aspect – it provides them with tools and opportunities to collaborate with other teachers in lessons or projects, and 2) the psychological aspect – it connects teachers with the same spirit and motivates them to set their beliefs into action. In the final section, I would like to propose several features an existing or newly emerging teacher’s online resource center can equip with in order to promote user’s interaction. For the proposed web application, I will employ the term “platform” instead of “resource center” to distinguish the collaborative purpose of a platform from the purpose of a resource center which is mainly instrumental.

4.5 Suggested features

4.5.a) Forum for discussion / announcement

WHAT:
- Users can post a discussion topic or an announcement.
- They can also copy their Twitter posts.
- The posts are visible whether to the whole platform users or to the members of a smaller community tagged by grade, subject, tool, or interest

WHY: Discussions can be useful when they want to brainstorm ideas or ask for advice on a certain issue. Such interactions enhance the sense of belonging among users. The database can be also used as a FAQ for those who have similar concerns in the future.

Targeting the audience community enables efficient information sharing and searching.

EXAMPLE:

Users can ask for opinions, ideas, helps or

Participatory projects can easily create

4.5.b) Schedule and planning

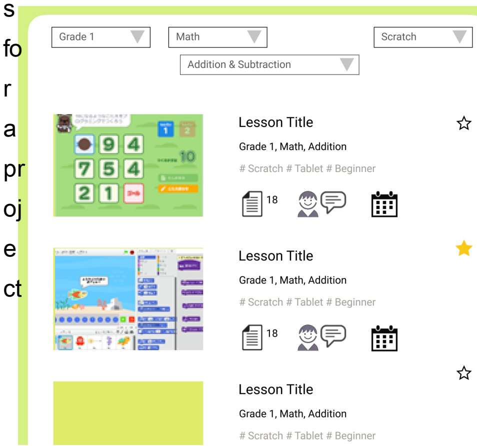
WHAT:
- When users plan to do a lesson from the resource of participatory activities, they can make it known on the public schedule. This means they are open for collaboration with other classes.
- Other users can let him/her know if they are interested in collaborating in the target lesson.
- They can make adjustments to the target lesson plan together and share students’ progress during the preparation sessions.

WHY: Connecting classrooms is a challenging job that requires a lot of consideration, planning and risk avoidance. But such devotion lets teachers learn from each other and gain deeper understandings on what students can achieve during the activities, and eventually could make the instructions more meaningful.

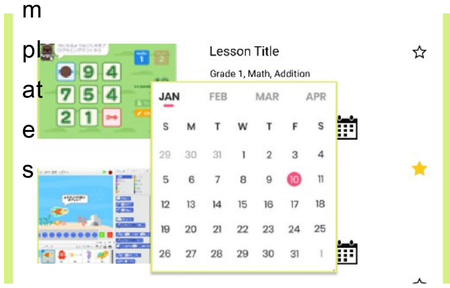
If both classrooms are well equipped and students can see each other’s classroom, they may feel more excited and try to be more creative. Even if they can’t see each other, sharing each other’s work is a more rewarding and motivating experience.

EXAMPLE:

articipants for a project



using templates



Tap the date when it's scheduled

e

entry to see the profile of the teacher

Upon submission of the teacher's profile of the fe

Feedback can al

4.5.c) <u>Lesson report</u>

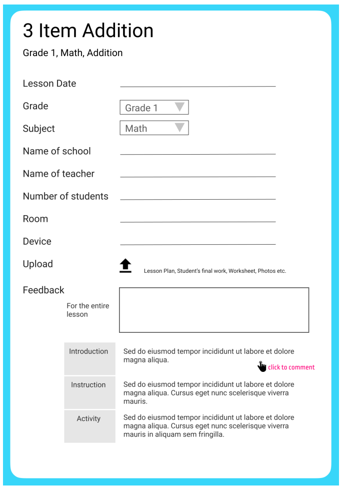
WHAT:
- Users can share the lesson report after a lesson is done
- Feedback can be both for the whole lesson and a section of lesson
- Materials can be also shared: worksheet, instruction slides, students' example work etc.
- After submitting a report, it will be added to the user's personal teaching record.

WHY: It makes the resource interactive. Since every classroom is different, a lesson that works for a class might not work for another. Other teachers' feedback for a lesson allows teachers to be better prepared for their own planning. It also enriches the uploaded plans with different versions.

It also promotes a teacher's sense of participation, resulting in higher motivation in teaching practice.

Visualized personal teaching records can help teachers reflect on their practice and effectively manage their planning for the following terms or years. It may also serve as a teaching portfolio.

EXAMPLE:



4.5.d) <u>Planning and Assessment tools</u>

WHAT:
- Tools that are helpful for planning CT education and assessing students' CT abilities are added

to the resource.

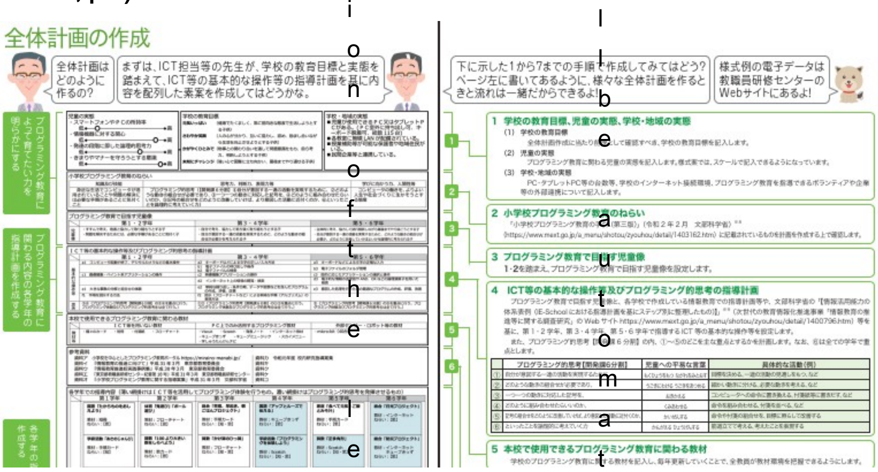
WHY: Guiding tools allow teachers to learn by doing about what to consider when planning CT education and analyze their students. That helps to increase teachers who can create lessons with clear objectives, making more quality resources shared on the platform in the future.

Skepticism about effects of programming education reported by Sakamaki & Fukushima's survey [13] can mitigate by establishing criteria for evaluating students' CT skills. These tools will contribute to the credibility of CT education and confidence of teachers for their practice.

EXAMPLE:

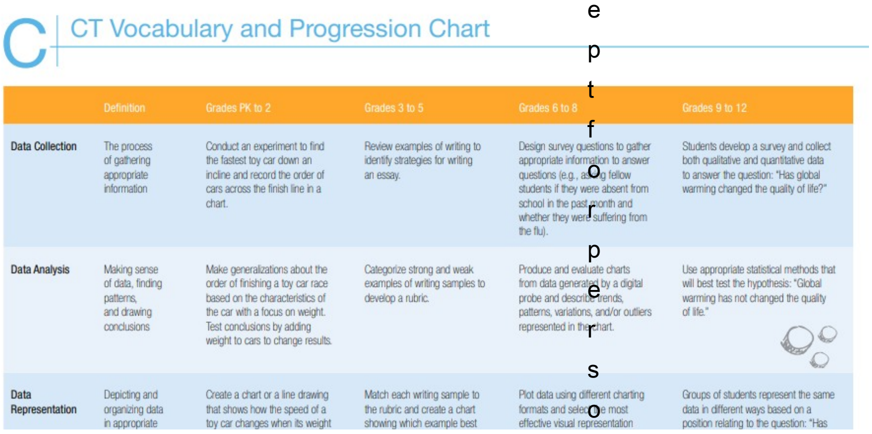
Below are examples of planning models and tools available for free.

CT education planning guideline (Source: Tokyo Metropolitan School Personnel In-Service Training Center, p.6)



The guideline provides templates to help schools to effectively map CT education in the school curriculum, and teachers to make a yearly plan, with consideration of educational visions of the school, regional characteristics, and available resources. Using these templates, teachers can learn how CT concepts can be integrated in other subjects and plan the students' learning path with clear intention. It improves the quality of lesson planning.

Progression chart of components of CT (Source: ISTE, p.14)



C CT Vocabulary and Progression Chart

	Definition	Grades PK to 2	Grades 3 to 5	Grades 6 to 8	Grades 9 to 12
Data Collection	The process of gathering appropriate information	Conduct an experiment to find the fastest toy car down an incline and record the order of cars across the finish line in a chart.	Review examples of writing to identify strategies for writing an essay.	Design survey questions to gather appropriate information to answer questions (e.g., asking fellow students if they were absent from school in the past month and whether they were suffering from the flu).	Students develop a survey and collect both qualitative and quantitative data to answer the question: "Has global warming changed the quality of life?"
Data Analysis	Making sense of data, finding patterns, and drawing conclusions	Make generalizations about the order of finishing a toy car race based on the characteristics of the car with a focus on weight. Test conclusions by adding weight to cars to change results.	Categorize strong and weak examples of writing samples to develop a rubric.	Produce and evaluate charts from data generated by a digital probe and describe trends, patterns, variations, and/or outliers represented in the chart.	Use appropriate statistical methods that will best test the hypothesis: "Global warming has not changed the quality of life."
Data Representation	Depicting and organizing data in appropriate	Create a chart or a line drawing that shows how the speed of a toy car changes when its weight	Match each writing sample to the rubric and create a chart showing which example best	Plot data using different charting formats and select the most effective visual representation	Groups of students represent the same data in different ways based on a position relating to the question: "Has

The chart lists the tasks related to each CT concept that learners are expected to perform according to their developmental stage (from Grades PK to 12). For example, regarding "Problem Decomposition," Grade 2 students can be given a task to create directions to a location in the school while Grade 8 students may be asked to plan the publication of a monthly newsletter by identifying roles, responsibilities, timeline and required resources. It helps teachers brainstorm activity ideas for their lessons, and assess student's CT skills in details through their work.

Dr. Scratch (Source: Moreno-León et al. [22])

After submitting the project URL, users receive a score for each concept of CT such as flow control, data representation, and abstraction and suggestions for improvement. Though it does not correspond to the educational objectives described in the Course of Study, the tool is still useful to increase student's autonomy in applying CT concepts.

5 Conclusion

As a society changes, the required quality for the people changes. Consequently, so does education. It is only natural that education is reformed on a regular basis and educators must review their acquaintance and methods. But theory without implementation plans does not work. While many barriers need to be removed, fortunately, several attempts are being made to create a more helpful environment for teachers and CT education by different levels: the government, public institutions and private organizations. However, such efforts are currently scattered and useful resources don't reach those who need them efficiently. When it comes to the online resource center, what is needed is strong initiatives to develop an integral space that is valuable to educators with various needs. Once the space gains a wide recognition and provides satisfaction to many users, it can become a norm in the educational sector.

The suggestions made in this paper aimed to promote CT education mostly through collaboration, but a teacher's platform with collaborative features will be useful for traditional areas of learning and teaching as well. And such networking can spread even internationally. With today's technology, establishing a culture of collaboration among educators is not a suggestion, but should be a plan.

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