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Article

Regional perspective on programming in Japanese elementary school

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Abstract: Japanese elementary schools introduced programming education in 2020, but are Japanese educators better equipped to teach this new subject? Most programming education research focuses on children. Unfortunately, educators are often overlooked. In this research, elementary schools in five Japanese prefectures were visited to understand better in-service educators' tasks and preparedness in teaching programming. An electronic survey was distributed to twenty-five schools, augmented by interviews with school principals. Data shows that while educators are recently better equipped to teach programming education compared to 2020, much work remains to be done in offering teachers pre-service training and lifelong learning opportunities. This paper provides insight into better professional development for Japanese elementary educators in programming education.

Keywords: programming; Japan; computational thinking; constructionism

1. Introduction

1.1. Programming education in Japan

In 2020, the Japanese Ministry of Education, Culture, Sports, Science, and Technology (MEXT) introduced programming education across all Japanese elementary schools. This initiative primarily targets 5th and 6th-grade students, although its implementation is not exclusively confined to these grades. The Guide to Programming Education, published by MEXT in 2022, along with the Miraino Manabi website, established this new subject's core principles. Importantly, it grants local education boards and schools the autonomy to tailor programming education to their specific contexts. Educators have been charged with the task of fostering "programming thinking" in students. This concept reimagines the four computational thinking skills—decomposition, abstraction, algorithm design, and pattern recognition—as originally delineated by Wing in 2006 [1].

While most research on programming education has concentrated on student learning outcomes, this research focuses on teaching strategies and professional development for educators. In Japan, teachers are finding themselves as learners, embarking on the relatively new journey of learning programming themselves in order to teach it—a subject previously untaught at the elementary level. Previous research has revealed that most educators had never studied programming themselves in 2020 [2].

Programming is not treated as an isolated subject within the Japanese educational curriculum but is integrated with traditional subjects. In 2020, it was mainly woven into mathematics and science lessons. The Miraino Manabi website offers various programming lesson examples in Japanese, from basic geometry to socially relevant topics like energy conservation and the Internet of Things [3].

The challenge lies in incorporating programming into an already dense curriculum, raising concerns among Japanese researchers about the rapid introduction's efficacy [4]. Before the official rollout in 2020, Kuroda [5] underscored the critical role of the training approach in enabling educators to understand and embrace the new programming curriculum. It was found that experiential and hands-on learning approaches were markedly more effective than traditional teacher training methods.

Government agencies and businesses in Japan advocate for programming education as a pivotal means to propel digital transformation (DX) and achieve the objectives of Japan's Society 5.0 initiative [6]. Society 5.0 represents a vision for a seamless integration of cyberspace and physical space, where technologies such as AI, big data, and robotics are leveraged to alleviate the burden of repetitive and manual tasks, thereby enhancing the quality of life for the Japanese population [7]. The push towards modernizing classrooms is bolstered by the establishment of the Japanese Digital Agency and the support from the private sector, notably through the Japan Business Federation (Keidanren). This consortium of companies actively advocates for workforce development to meet the burgeoning needs of a digitally-oriented economy [8]. Japan's educational system is tasked with teaching what is needed for all students to align with the business sector's expectations and the government's ambition for realizing Society 5.0.

Although Japan is ranked among the top 10 countries in science and mathematics, according to the 2018 Programme for International Student Assessment (PISA) conducted by the OECD Education GPS, its standing in terms of digital competitiveness lags behind other members of the Organization for Economic Co-operation and Development (OECD) and the Group of Seven (G7) [9]. Specifically, Japan was ranked 29th out of 63 countries in the 2022 survey by the International Institute for Management Development [10]. Notably, this survey pinpointed Japan's utilization of big data and analytics and digital and technological skills as the primary areas of weakness.

The implementation of programming education, aimed at addressing Japan's digital skill gaps, was fortuitously aligned with the launch of Japan's Global and Innovation Gateway for All (GIGA) project. This project aims to equip every Japanese student with computing devices, such as laptops and tablets, ensuring universal access to digital learning tools [11]. The GIGA project's rollout gained momentum in response to the COVID-19 pandemic, which necessitated a reevaluation of technological utilization in education, including adopting learning management systems (LMS) to facilitate remote instruction. Furthermore, the project is advancing towards piloting a national cloud platform designed to integrate these devices, enhancing the coherence and efficiency of digital education across the country [12].

The year 2020, was the start of an educational reform in Japan, programming was introduced as a mandatory subject in elementary schools, coinciding with English being made an obligatory course of study. The integration of English education, which had undergone several years of reform before its official inclusion, represents a significant shift in the curriculum. Although this paper does not delve deeply into adopting a Content and Language Integrated Learning (CLIL) approach in conjunction with programming education, it is noteworthy that educators were queried about their interest in utilizing English as the medium of instruction for programming.

Table 1, shows the evolution and impact of these reforms on the educational landscape. The introduction of programming education, alongside the sudden surge in the availability of electronic devices, has not only enriched the teaching environment but also introduced additional responsibilities for educators. This dual introduction has created a dynamic setting where the potential for innovative teaching methodologies but faces an increase in the workload of educators.

Table 1. Computer programming and accessibility before 2020 to present.

	Before 2020	**From April 2020**	**2022-present**
What programming is being taught?	Some schools offer basic programming on an individual basis.	Schools started offering programming for the 5th and 6th grade math and science class.	Schools offer programming throughout the whole curriculum and are not limited to 5th and 6th grades.
Computer accessibility	Students have limited access to devices	The GIGA project was launched early, all elementary school children received a tablet or a laptop.	Schools are well equipped with devices.

1.2. Theoretical framework

This research is guided by Change Theory, a framework developed by Fullan [13], which outlines the complexities associated with implementing changes within educational institutions. According to Fullan, key factors such as self-confidence among educators and robust institutional support are crucial for the successful adoption of reforms. This research aimed to gauge educators' confidence in their abilities within this context through school observations and surveys.

Typically, investigations based on Change Theory might be conducted by a Board of Education (BOE) or within a school district, encompassing a collaborative effort among all teachers. However, due to the inherent self-selection bias in our study, the study is limited to engaging with educators who volunteered to participate. By surveying schools across a broad geographical spectrum encompassing various prefectures, our research seeks to paint a more comprehensive picture of the educational practices and challenges encountered.

This research also explored programming integration within a Content and Language Integrated Learning (CLIL) framework. CLIL, which combines language learning with content instruction, presents a novel approach in the context of programming education. Researchers Domenach et al. [14] have highlighted the introduction of digital devices alongside the new programming curriculum as paving the way for innovative educational practices. Specifically, they suggest that programming instruction, facilitated through the use of accessible English, can significantly enhance learning outcomes. The dual introduction of programming education and the provision of computers on a one-to-one basis offer educators a unique opportunity to innovate within their curriculum strategies. Notably, English and programming are subjects for which many in-service educators have not received formal training yet are now required to teach as per the Ministry of Education, Culture, Sports, Science, and Technology (MEXT) mandates.

1.3. Background

In Japan, elementary school curricula encompass a wide range of subjects as mandated by the Ministry of Education, Culture, Sports, Science, and Technology (MEXT). These subjects include Japanese language, social studies, mathematics, science, living environment studies, music, arts and crafts, home economics, physical education, moral education, special activities, a period designated for integrated studies, and foreign language activities. All Japanese schools are required to cover this comprehensive curriculum outlined by MEXT. While managed by local Boards of Education, elementary schools must adhere to these national curriculum guidelines, which permit content addition but prohibit any reduction from the established curriculum [15].

Since 2020, MEXT has mandated the inclusion of programming activities in the curriculum, although it has not been designated as a separate subject. According to the MEXT Guide to Programming Education [16], these activities are primarily integrated within mathematics and science lessons, with each officially approved 5th and 6th grade textbook featuring at least one programming lesson.

English education officially became a subject after the last curriculum amendment, marking a significant shift from its previous status. Since 1987, the enhancement of English language instruction has been a priority, supported through the weekly engagement of an Assistant Language Teacher (ALT). These ALTs, hired either directly by MEXT or through private companies, play a crucial role in this initiative. The Japanese educational system's commitment to foreign language education is further underscored by substantial financial investment and the annual recruitment of new ALTs, demonstrating a sustained effort to bolster English proficiency among students.

Japan is not the first country to introduce programming at the elementary level. The United Kingdom started introducing children to programming in the regular curriculum in 2014 [17]. In Japan, the newly revised curriculum for programming education is designed to foster "programming thinking" among students through engaging and playful activities. This approach draws heavily on constructionist principles, as detailed in the official MEXT documentation. According to these guidelines, children are encouraged to engage in experiential learning, embracing a process of discovery and understanding through project-based activities without the fear of making mistakes. This educational philosophy is similar to what is found in the work of Resnick [18] which advocates for an environment where students are encouraged to learn from their mistakes and explore concepts through trial and error. The MEXT documentation specifically advises educators to create a classroom atmosphere conducive to experimentation, allowing students to benefit from the learning opportunities presented by their attempts, successful or otherwise.

The distribution of the survey, coupled with informal discussions with officials at local Boards of Education (BOE) and school principals, helped clarify the educational landscape. Large BOEs, exemplified by Kumamoto (Japan) City BOE, employ a dedicated Information and Communication Technology (ICT) and programming coordinator. This coordinator is pivotal in facilitating the training of educators and ensuring that each school is equipped with the necessary pedagogical materials for effective ICT and programming instruction.

The training provided to educators lacked uniformity since most local BOEs do not have dedicated staff for technology training. Each BOE dealt with different technologies due to the GIGA Project forcing them to decide between iPads and Chromebooks, with a tiny fraction using Microsoft computers. Predominantly, these BOEs opted for Loilo Note software, facilitating communication between educators and students [19]. This software enables teachers to distribute educational content and allows students to compile a digital portfolio [20]. Additionally, Loilo Note supports real-time teacher surveys, which can instantaneously showcase results on smart boards.

2. Materials and methods

2.1. Research questions

This paper aimed to answer the two following questions: (RQ1) Were Japanese elementary school teachers ready to teach programming in 2022? (RQ2) What type of programming training did elementary school teachers receive to prepare them to teach programming? Additionally, this paper will tackle the following questions: Was there an improvement in the confidence of teachers from 2020 to 2022? Was there an improvement in the training teachers receive from 2020 to 2022?

2.2. Survey procedure

Electronic surveys, available in Japanese and English, were distributed to elementary school educators in five prefectures in Japan: Kumamoto, Fukuoka, Oita, Hiroshima, and Hokkaido, using Google Forms. Initially, visits were made to these prefectures' Boards of Education (BOEs) to secure permission for survey distribution within their schools. Following this, individual schools were approached, and discussions with the principals were held to explore the feasibility of administering the survey to their educators. The researcher tried to contact the same schools that were surveyed in 2020. Only one answer came from a school previously surveyed.

Convenience sampling was employed for this survey, limiting the geographical coverage to select regions of Japan. However, the chosen Boards of Education (BOEs) were intended to reflect a wide range of both urban and rural educational settings. In September and October 2022, twenty-five schools were visited, resulting in forty-three respondents from twelve schools participating in the survey. The majority of responses were gathered from the island of Kyushu, with detailed contributions from five teachers in Oita, three in Fukuoka, and thirty-one across seven schools in Kumamoto. The selection bias towards Kumamoto, where the researcher is based, was a pragmatic choice due to logistical accessibility. Additionally, responses were received from one teacher in Hiroshima and three from Otaru in Hokkaido.

The school visits facilitated the survey distribution and provided insightful observations into the implementation of programming education. These visits included informal interviews with school principals, allowing for spontaneous discussions that enriched the research findings. Principals frequently shared their perspectives on the integration of the programming curriculum and recommended other schools for potential inclusion in the study. This approach underscored principals' autonomy in curriculum delivery and highlighted the varied implementation strategies across schools.

In the structured survey comprising nineteen questions (Appendix A), eighteen were designed as multiple-choice, and the final question was open-ended, essay-type, allowing educators to share their personal impressions. At the principals' suggestion, the second survey was streamlined to accommodate educators' schedules by reducing the number of questions. Some of the questions were derived from the Technological, Pedagogical, and Content Knowledge (TPACK) framework [21].

Notably, due to logistical constraints, the initial 2020 and the subsequent 2022 surveys involved different schools, introducing a limitation in the longitudinal analysis. The questions in the second survey, while akin to the first, were adjusted to better capture the dynamics of programming education two years post-implementation.

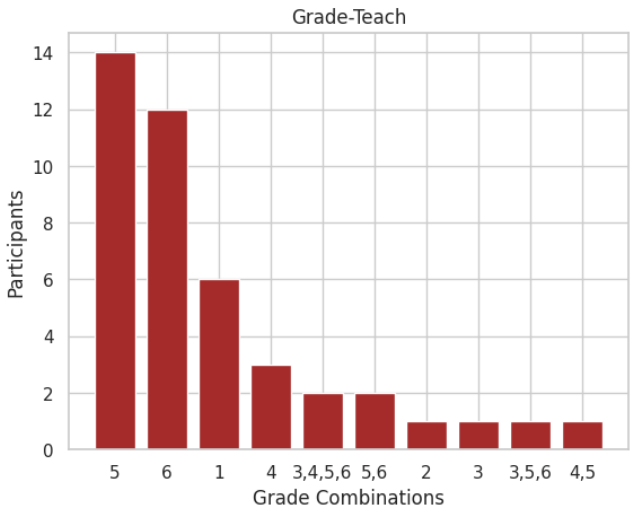
Statistical analysis of the collected data was performed using R and RStudio programming languages, employing Exploratory Data Analysis (EDA) through the DLOOKR package. DLOOKR facilitated a diagnostic review of data quality and provided comprehensive bivariate analysis, which is crucial for understanding the dataset's characteristics and relationships.

The COVID-19 pandemic significantly impacted the data collection process for the surveys conducted in 2020 and 2022 as part of this research. During the initial survey in 2020, teachers were heavily engaged in developing and distributing remote learning materials, hence participation in the distributed survey was limited. Furthermore, it was established early on that individual interviews with teachers would not be feasible. By the time of the second survey in 2022, although the situation had marginally improved, direct access to teachers for survey participation remained constrained. In both instances, direct classroom observations were precluded by the ongoing pandemic conditions. However, school principals emerged as an invaluable resource, offering critical insights into implementing programming education within their institutions and across their respective boards of education.

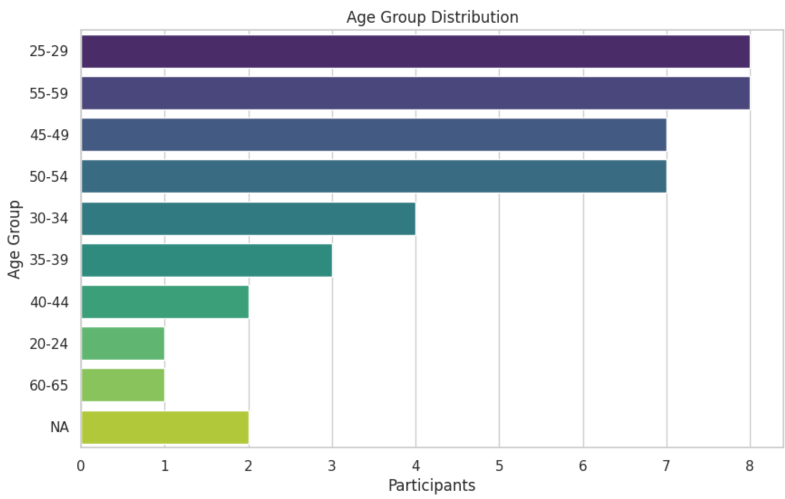
3. Results

3.1. Survey taker

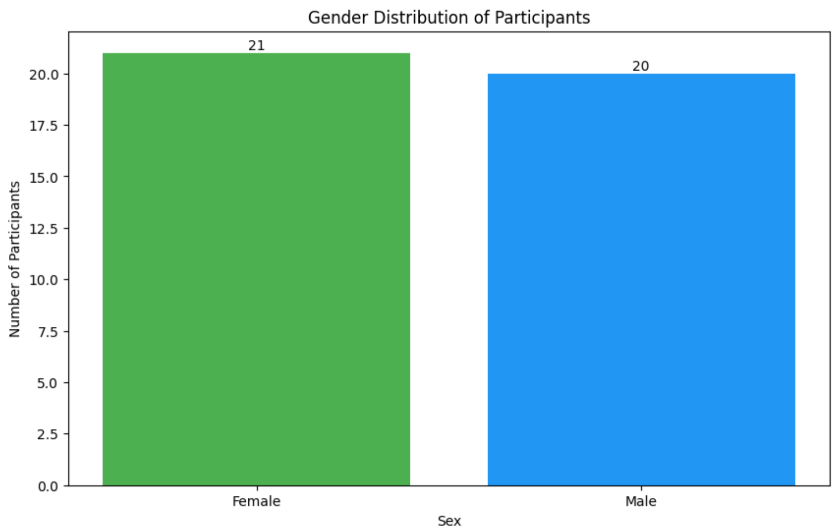
Forty-one educators agreed to participate in the survey, with an equitable gender distribution of twenty male and twenty-one female respondents (**Figure 1a**), as shown in **Figure 1**. When inquired about their experience with teaching programming since its mandated introduction in 2020, 55.8% indicated they had not taught the subject. Predominantly, the respondents taught 5th and 6th grades (**Figure 1c**)—the focus of MEXT's programming education initiative. The distribution of respondents spanned equally across both new and experienced educators, offering a balanced perspective on the implementation challenges and successes of programming education (**Figure 1b**). The biggest age group is 25 to 29 years old and 55 to 59 years old.



(a) Grade taught



(b) Age



(c) Gender

Figure 1. Survey of teachers **(a)** grade taught ; **(b)** age; **(c)** gender.

Table 2 provides a detailed breakdown of the schools involved in the second survey in 2022. Despite efforts to engage educators from the initial 2020 survey, anonymity constraints meant that only one teacher was confirmed to participate again. This anonymity also precludes definitive tracking of whether this individual's responses were captured in both survey iterations. Predominantly, the schools participating in the follow-up survey were situated on the island of Kyushu.

Table 2. School location of teachers that participated in 2022.

School location	Prefecture	Teachers
Jinsekikogen	Hiroshima	1
Otaru	Hokkaido	1
Taketa	Oita	5
Yame	Fukuoka	2
Kurume	Fukuoka	1
Tamana	Kumamoto	10
Hanazono	Kumamoto	1
Ikeda	Kumamoto	1
Takahiradai	Kumamoto	10
Kumamoto ES	Kumamoto	1
Miyuki	Kumamoto	5
Takaki	Kumamoto	3

3.2. Confidence in using technology in the classroom and readiness to teach

In the 2022 survey concerning the teaching environment and educators' confidence in teaching programming, 93% of respondents indicated that their schools provided the necessary support for enhancing their programming teaching skills. Most notably, confidence in utilizing technology within the classroom showed a positive shift, increasing from 45% in 2020 to 51% in 2022. Furthermore, 74% of educators reported having studied programming, a significant 24% increase from the previous survey. However, the survey did not delve into the specifics of how educators pursued programming studies—highlighting a need for further research to explore the nature of their training, including whether it was mandatory or self-initiated.

As detailed in **Table 3**, there has been an observable overall increase from 2020 to 2022 in the number of educators engaging in programming studies and their readiness to teach programming. In 2020, only one board of education, located in a rural area of Hiroshima, had provided all students with individual devices. In contrast, other schools visited mainly relied on computer labs for digital learning.

Table 3. Differences between 2020 and 2022 survey results of teachers.

	Studied programming	One device per child	Overall confidence in using ICT	Ready to teach programming
2022	74% yes	100% yes	51% positive	48.5% yes
2020	50% yes	32% yes	45% positive	13.6% yes

In 2020, nearly all schools restricted programming education to 5th and 6th grades, per the official curriculum. However, the 2022 survey depicts a shift, with only 14% of schools maintaining this limitation. Yet, fewer than half of the educators (48.8%) support integrating programming throughout the curriculum, indicating some resistance to broader integration. The survey did not delve into the reasons for this hesitation, suggesting that detailed interviews with educators could provide further insights into their reservations about programming's role in education.

Furthermore, to examine the relationship between educators' programming education and their confidence in using ICT, a Welch's *t*-test for unequal variances was conducted, as detailed in **Table 4**. The results indicated no significant difference between the two groups, with a *p*-value greater than the 0.05 significance level and a negative *t*-statistic suggesting a minimal true difference. The limited number of responses may have influenced these findings.

Table 4. *T*-test between 2020 and 2022 survey.

	Studied programming	Confidence ICT
Estimated mean difference	−0.244	−0.0317
Estimated mean 2022	0.5	3.36
Estimated mean 2020	0.744	3.40
t-statistic	−1.90	−0.128
p-value	0.0646	0.899

The teacher's answers were submitted to an exploratory data analysis (EDA) using the DLOOKR package in R. **Table 5** below summarizes the linear model resulting from a bivariate analysis. The analysis allows us to verify the linear model of all data.

Table 5. Linear model teachers.

First variable	Second variable	*R*-squared	Adj. *R*-squared	*p*-value
Male	confidence_ict	0.205	0.185	0.002
coding_2020	understand_ct	0.186	0.166	0.003
confidence_ict	understand_ct	0.542	0.531	0.001
play_important	ct_important	0.286	0.268	0.001
all curriculum	coding_english	0.181	0.161	0.004

The DLOOKR EDA results, as seen in **Table 5**, reveals interesting correlations concerning how the knowledge of ICT and familiarity with technology positively impact the teaching and, by extension, the student's learning experience.

The first result found that the male teachers showed greater overall confidence in ICT and felt they had acquired more confidence since 2020. While the research did not focus on the difference between male and female teachers, these results suggest that greater attention will be needed to create an inclusive training environment in the future.

In examining the bivariate relationships presented in the dataset, the connection between educators' confidence in using ICT and their understanding of computational thinking (CT) stands out as particularly significant. The statistical analysis indicates an extremely low *p*-value of less than 0.001, denoting a highly significant statistical relationship. Furthermore, this finding is reinforced by the highest *R*-squared value in the dataset, 0.542, suggesting that confidence in ICT accounts for approximately 54.2% of the variance in educators' understanding of CT. Additionally, the relationship between the perceived importance of play in education (play_important) and the importance assigned to CT (ct_important) is notably significant. Although the *R*-squared value of 0.286 for this pair is lower, indicating a less strong relationship compared to the first, the *p*-value stands at 0, signifying another statistically significant relationship within the dataset. These results collectively highlight the influential role that confidence in technology plays in educators' grasp of computational thinking concepts and the recognized value of playful engagement in education's embrace of computational thinking.

The data reveals a clear trend among educators who have pursued studies or gained experience in coding since 2020: they not only demonstrate a better understanding of computational thinking (CT) but also express a greater inclination to expand the reach of programming education across the entire curriculum, including integrating coding into English language activities. Moreover, educators who advocate for a playful approach to teaching methodologies show a significantly stronger grasp of computational thinking, underscored by a *p*-value of less than 0.001. Additionally, those educators who support the comprehensive inclusion of English throughout the curriculum are also more likely to endorse the teaching of coding in English, as evidenced by a statistically significant *p*-value of 0.004. This data suggests a link between educators' continuous learning and coding experience, pedagogical preferences, and attitudes towards innovative curriculum integration.

3.3. The state of teacher training in 2022

In 2020, initial programming lessons were incorporated expressly within 5th and 6th-grade mathematics and science classes. School principals reported that training was mostly done internally by teachers who were more technically inclined or provided by the local board of education trainers. As of April 2020, all science and mathematics textbooks included at least one lesson on programming education [2]. Prior surveys and interviews have indicated that most schools adhered to this guidance, confining their programming instruction to these subjects. However, the official MEXT Guide to Programming Education and the supporting website did propose the possibility of integrating programming into other subject areas

By 2022, the scope of programming education had notably broadened, extending to other subjects and grade levels, with individual schools often determining the specifics of implementation, even within the same Board of Education (BOE). According to our survey, 86% of respondents reported that programming was no longer restricted to just mathematics and science lessons. While the survey did not investigate which additional subjects now include programming, principals from several schools have mentioned its inclusion in art classes.

Programming education has gradually become a more integral to the entire school curriculum. Students engage with simple pattern drawing and animation from an early age using Viscuit software. Tablets provided to the children are preinstalled with Scratch Jr and Scratch visual programming languages, starting from the first grade, allowing them to explore programming both in school and at home.

The survey results show that 58% of educators reported an increase in confidence in teaching programming since 2020. However, there is only a weak correlation between having studied programming and this increased confidence, as indicated by a Pearson correlation coefficient of 0.172. Although this coefficient value typically signifies a weak relationship, it is worth noting. Nonetheless, the p-value associated with this correlation is 0.271, which is above the commonly accepted threshold for statistical significance of 0.05, indicating that the relationship is not statistically meaningful. The limited sample size could be a contributing factor to these inconclusive results. This situation might also mirror a broader context where educators, despite reporting higher confidence, may still not feel at ease with implementing programming education. In line with this, a study from Norway by Kravik [22] found that even after formal training in programming, teachers may still face challenges in teaching the subject, suggesting a need for sustained professional development to enhance their self-efficacy.

3.4. Innovative practices in programming education

Educators were surveyed regarding the future trajectory of programming education and its potential integration with English language teaching. Choosing to survey educators about a limited adoption of English within programming is a way to measure their willingness to combine programming with English, a subject with which most teachers are uncomfortable with. This question was also added following interviews with school principals in 2020 and their inquiry about the possibility of combining English and programming. Since 2020, English has been an official subject for 5th and 6th graders, with mandatory English activities introduced for 3rd and 4th graders. While 58% of Japanese elementary educators teach English, responses to incorporating programming instruction in English or within a Content and Language Integrated Learning (CLIL) setting were mixed: 41.9% were neutral, while 33% disagreed or strongly disagreed. This suggests the need for further investigation into the confluence of programming and English education in Japan.

The private sector, represented by companies such as Tokyo Coding Club, Coding Lab, and Little Hackers, has already adopted the CLIL methodology for programming instruction. Future research should assess whether such initiatives by the private sector might contribute to a digital divide, particularly in a context where global companies in Japan are increasingly adopting English as the lingua franca [23]. While the CLIL approach has been studied in higher education, its application and research within the K-12 system in Japan remain limited and warrant more comprehensive study.

3.5. Open-ended questions regarding readiness and the need for training

The survey concluded with an open-ended question: "What were the biggest challenges in teaching programming education?" 31.7% of respondents chose to provide answers, revealing the perceived complexities involved in introducing this novel subject. The teachers' answers give a clearer view of teachers' readiness and their view on training. Although personal interviews with educators were not part of this study's methodology, the insights derived from the open-ended responses strongly advocate for including such interviews in future research to delve deeper into these challenges. To accommodate educators' schedules, the survey was intentionally concise. However, this approach may have overlooked the potential benefits of gathering detailed insights into the advantages of teaching programming. Future iterations of the survey could be enhanced by including questions that explore the challenges and the perceived benefits of programming education, thereby providing a more comprehensive understanding of its impact on the educational landscape.

The answer from the teacher reflects a lack of confidence in ICT, "Very bad at ICT", "Difficult to teach programming", "Teaching by educators with little expertise". Some comments address the time needed for preparation, "It takes time to prepare teaching materials. It started recently, and when I started teaching, I had to create teaching material from scratch."

A few comments address equipment issues, "Fixed issues with tablet, and time adjustment. Securing time for meetings with the ICT support staff and preparing material", "Solve problems such as connection failure, updates, and unsupported connections between programming materials and tablet terminals". One educator remarked the difficulty in finding the right software, "There are various programming software and applications, and it takes time and effort to find out which application is practical for teaching children."

Some of the comments look at the response from the children in the classroom, "There were times when the children could not understand because the language was difficult." And more particularly the difficulties of offering a differentiated learning experience, "There are large individual differences, and it is difficult to respond to each individual."

The confidence issue was highlighted in the two following comments, "I have not confidence in my teaching" or "I feel uneasy about teaching programming education in a field where I do not have confidence in myself." (Appendix B)

4. Discussion

4.1. Increase in teachers' confidence

Educators in 2022 felt more ready to teach programming. While there has been an increase in ICT confidence among educators, principals and BOE authorities have underscored the ongoing need for further training and lifelong learning opportunities. The survey data reveal that while educators recognize the value of teaching programming through playful methods, approximately 23.3% are uncertain about how to teach computational thinking effectively. Notably, in 2022, 86% of educators reported that programming education extends beyond mathematics and science classes, indicating a significant shift towards embracing the new curriculum and possibly an increasing ease in adopting programming in other subjects. This evolution underscores the critical role of hands-on learning in teacher training, suggesting that Japan could benefit from adopting approaches similar to those in Singapore, where pre-service programming education training is standard [24].

Personal visits to schools provided unique insights into the disparities in training opportunities among educators, with a notable difference observed between larger urban BOEs and their smaller counterparts. Urban BOEs often had dedicated programming education support staff and were equipped to provide robotic kits with dedicated trainers to schools, facilitating enhanced learning experiences. In contrast, smaller BOEs tended to rely more on self-initiated learning. Future research should investigate whether there is a direct correlation between educators' confidence in teaching programming and their geographical location, exploring the potential advantages of urban versus rural settings in providing comprehensive programming education.

4.2. Changes in teaching environment

While the survey did not explicitly query educators on the GIGA project's impact, observations during school visits have revealed a significant enhancement in technological resources available for programming education by 2022. Contrastingly, in 2020, many schools had to depend on a limited number of devices, often transported to classrooms on carts or accessible only through the computer room. This has notably shifted by 2022, with principals and Boards of Education (BOEs) universally recognizing the GIGA project—aimed at providing every child with a personal device—as a pivotal factor in this transformation. The increased access to technology, as facilitated by the GIGA project, has equipped educators with the necessary tools to implement programming education more effectively.

All schools have now installed Scratch software on their devices, a platform widely used for teaching programming concepts. Furthermore, some schools have also adopted the Viscuit software, particularly for younger students, to enrich their programming curriculum further. Principals have observed that the investment in technology has compelled educators to incorporate these digital tools into their teaching practices. However, the extent and manner of device utilization still vary significantly among educators, as noted during informal interviews with school principals. This variability underscores the need for further investigation into how these technologies are being integrated into programming education and their overall impact on teaching and learning outcomes.

4.3. Educators' readiness and training challenges

In 2022, the teachers have better access to training and have accumulated first-hand experience in teaching programming education. The exploratory data analysis (EDA) conducted as part of this study underscored the critical role of providing all educators with access to training opportunities, thereby enhancing their sense of agency in adopting new teaching methodologies. Notably, a shift in attitude toward programming education was observed between 2020 and 2022. The EDA from 2022 specifically highlights how two years of practical teaching experience in programming significantly influences educators' perceptions of their responsibilities and their adaptability to incorporating new subjects into the curriculum. A foundational understanding of programming has been instrumental in elevating the confidence levels of educators, a factor that Change Theory has previously identified as vital for facilitating curriculum transformations. This analysis suggests that empowering educators with basic programming knowledge is a key strategy for supporting positive changes in educational practices.

The feedback from educators on the challenges associated with teaching programming underscores a significant need for greater confidence in navigating new technologies and allocating more time for professional development. This sentiment mirrors the broader challenges Japanese educators face, who are identified as some of the busiest worldwide, as per the 2018 Teaching and Learning International Survey (TALIS) conducted by the OECD [25]. Notably, this study also revealed that Japan's educators report the lowest self-efficacy in ICT usage among all OECD countries, at 35%, compared to an OECD average of 67%. Rather than viewing this deficiency in expertise as a setback, it should be embraced as an opportunity for educators to adopt a learner's mindset. This perspective shift enables educators to transparently communicate with their students about the iterative nature of learning, demonstrating how to leverage online resources and trial-and-error methods for problem-solving. Such an approach facilitates educators' professional growth and serves as a valuable teaching method, showcasing real-world problem-solving and continuous learning strategies to their students.

4.4. Attitude toward innovative practices

Over half of the Japanese educators surveyed are currently engaged in English language instruction. Although the primary aim of this survey was not to assess their confidence in teaching English, it revealed a notable reluctance among educators to integrate programming instruction with English language teaching. There is a clear need for initiatives to bolster educators' confidence in English instruction and broaden the application of English in classrooms to encompass more CLIL activities. In Fukuoka, one Board of Education (BOE) has pioneered such an approach in an elementary school, employing a foreign educator to teach programming alongside English in what could be described as a "soft" CLIL approach. This method of integrating content and language learning is gaining traction in larger BOEs, with efforts underway to introduce similar classes at the junior high school level. Given the novelty of CLIL programming activities, this area presents a fertile ground for further research to explore its effectiveness and impact on language and programming education.

4.5. From the perspective of change theory

Between 2020 and 2022, it is possible to observe a change in confidence, as previously illustrated in **Table 4**, and ways programming education is becoming more prevalent throughout the curriculum. The same period previously described in **Table 2** saw a radical change in the ICT landscape of all Japanese schools when devices were quickly made available under the GIGA project. Change theory emphasizes institutional collaboration at all levels, and the visits to schools and BOE in 2022 revealed that the support structure for educators has improved.

The initial survey conducted in March and April of 2020 drew inspiration from the Technological, Pedagogical, and Content Knowledge (TPACK) framework developed by Koehler and Mishra [2] [21]. This survey sought to gauge Japanese educators' familiarity with programming (Content Knowledge), their pedagogical strategies for teaching this subject (Pedagogical Knowledge), and, critically, their technical proficiency for imparting computational thinking skills (Technological Knowledge). As indicated in **Table 4**, the findings revealed a general unpreparedness among educators regarding the introduction of programming education. This included a particular discomfort with utilizing technology that was previously unfamiliar to them, mirroring a broader lack of confidence in employing ICT.

The subsequent survey in 2022, detailed in **Table 6**, depicted a dramatically transformed technological landscape, underscored by significantly improved access to technology. However, interviews with school principals highlighted that despite this enhanced access, faculty members continue to encounter challenges in effectively integrating these new devices into classroom instruction. The widespread introduction of tablets, in particular, has necessitated educators to devise strategies for incorporating technology across the curriculum, extending beyond the confines of programming education.

Table 6. Difference in teacher's opinion between the first and second survey.

	First survey	**Second survey**
Change Theory confidence	Conducted one month before the start of the 2020 school year. Educators are nervous about adding a brand-new subject to the curriculum.	The educators have been teaching programming for two years. Increase in confidence.
Change Theory implementation	The new programming must be implemented in two specific grades.	Educators are exploring how to integrate programming throughout the curriculum.
TPACK curriculum	Most teachers report having little knowledge of programming education.	Teachers are more familiar, and more teachers are reporting that they have studied programming.
TPACK new technology in the classroom	Most teachers are worried about the usage of new devices which are about to be distributed in all schools.	The new devices are readily available. Some principals report that some staff are still struggling with using the tablets in the classroom.

5. Conclusion

In 2020, Japan initiated programming education to bridge the technological gap between other nations. The data from 2022 show an improvement in teachers' readiness (RQ1) and training (RQ2). Two years post-implementation, it has become clear that while educators are eager to learn and adapt their curricula to the rapidly evolving technological landscape, challenges persist. Survey data from 2020 to 2022 indicate a growing willingness among educators to embrace programming education, yet responses to open-ended questions expose a prevalent discomfort with navigating unfamiliar subjects. To keep pace with global standards, Japan must enhance its curricular changes by ensuring educators can access superior training opportunities, emphasizing a hands-on, experiential learning model.

There is a pressing need for local universities to elevate pre-service teacher training and extend resources to in-service educators, enabling them to stay abreast of technological advancements. Moreover, developing a national strategy, potentially encompassing online training programs and comprehensive digital support, could significantly bolster educators' proficiency, regardless of their geographic location. Although the latest survey did not explore the concept of a community of practices, findings from the 2020 iteration underscored the potential advantages of establishing a structured online community focused on programming and ICT. Such a community could be a pivotal resource for Japanese educators, facilitating shared learning and collaborative problem-solving in integrating programming into classroom instruction.

Future work

Further school visits are necessary to understand the state of programming education in Japanese elementary schools. Future research will expand the number of educators surveyed and cover a larger geographic area. The visit to individual schools has proven to be a precious source of first-hand information on the nature of the deployment of programming education. While the discussion with the principals offered a bird's eye view of each school, classroom observation and one-on-one interviews with educators could further reveal what is needed to improve future educator training and professional development opportunities.

In response to the need for lifelong learning opportunities, the researchers intend to invite local elementary educators to visit the university IoT lab, where university students of the IoT computer club will lead accessible programming workshops where educators can experiment with easy IoT projects. By having Japanese computer science students introduce the activities, it will encourage the educators to participate actively in each activity. The workshop will encourage all to adopt a playful approach where making mistakes will be encouraged. Additionally, the researcher would like to extend this activity to the local elementary schools.

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Appendix A

Survey questions and answer format:

1. Name 「名前」（回答は任意です）
2. Email 「メール」（回答は任意です）
3. Sex 「性別」
4. Age 「年齢」
5. What grade do you teach? You can check more than one box. 「あなたは何年生を教えていますか？」（複数回答可）
6. Did you teach programming education since April 2020? 2020 年 4 月からプログラミング教育を担当されていますか？
7. Have you ever studied computer programming or coding? 「プログラミングやコーディングを勉強したことがありますか？」(yes/no answer)
8. I feel confident in using computers and ICT tools in my teaching practice. 「私は授業でコンピュータと ICT ツール を使うことに自信があります。」(5-point Likert scale)
9. My school offers me the support needed to learn and improve my knowledge of ICT. 「あなたの学校では、ICT の知識を向上させるためのサポートをしてくれますか？」(5-point Likert scale)
10. Has your confidence in your ability to use education technology increased, decreased, or stayed the same since the introduction of programming education in April 2020? 2020 年 4 月のプログラミング教育導入後、教育のためのテクノロジーの活用に対する自 信は増えたか、減ったか、変わらないか。 (5-point Likert scale)
11. Do you think you are understanding how to teach computational thinking (programming education) to your students? 「生徒にプログラミング教育を教える方法がわかりますか？」(5-point Likert scale)
12. It is important that children learn about programming in a playful manner? 「子どもたちが遊びの中でプログラミングを学ぶことは重要だと思いますか？」(5-point Likert scale)
13. Is it important that children develop computational thinking capabilities? 「子どもたちがプログラミング的思考力を身につけることは重要だと思いますか？」(5-point Likert scale)
14. Was programming education limited to math and science classes? 「プログラミング教育は、数学と理科の授業内での実施に限られていましたか？」(yes/no answer)
15. I think programming education should be integrated throughout the whole curriculum. 「プログラミング教育は、カリキュラム全体を通して他の科目と統合されるべきだと思 いますか。」(5-point Likert scale)
16. Do you currently teach English? 「現在英語を教えていますか？」
17. Do you think some of the easy programming lesson can be offer during English class? For example, directions. 「英語の授業内で、簡単なプログラミングの内容を扱えると思いますか？」(5-point Likert scale)
18. I feel like my students enjoyed learning about programming. 生徒たちは楽しんでプログラミングを学んだと思いますか？ (5-point Likert scale)
19. What were the biggest challenges in teaching programming education? プログラミング教育で一番苦労したことは何ですか？ (自由記述) Open-ended question

Appendix B

Open-ended question answers:

1. “Very bad at ICT.”
2. “Difficult to teach programming.”
3. “Teaching by educators with little expertise.”
4. “It takes time to prepare teaching materials. It started recently, and when I started teaching, I had to create teaching material from scratch.”
5. “Fixed issues with tablet, and time adjustment. Securing time for meetings with the ICT support staff and preparing material.”
6. “Solve problems such as connection failure, updates, and unsupported connections between programming materials and tablet terminals.”
7. “There are various programming software and applications, and it takes time and effort to find out which application is practical for teaching children.”
8. “There were times when the children could not understand because the language was difficult.”
9. “There are large individual differences, and it is difficult to respond to each individual.”
10. “I have no confidence in my teaching.”
11. “I feel uneasy about teaching programming education in a field where I do not have confidence in myself.”