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Japanese teachers' mental readiness for online teaching of mathematics following unexpected school closures

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ABSTRACT

Teaching mathematics online has been highlighted as one of the solutions to the current crisis for education caused by the COVID-19 virus pandemic and subsequent school closures. However, we do not know what attitudes and experience teachers have towards online teaching. The aim of this study was to gain insights into how Japanese teachers were mentally prepared to tackle online teaching, in particular, when they faced a sudden, unexpected and challenging situation caused by factors beyond their control. Data was gathered from 207 elementary/junior high Japanese teachers using a survey in April 2020. Most participants held relatively positive attitudes towards the use of online teaching of mathematics. Their sense of crisis was very high, and they were anxious about, (a) how to actually make their teaching interactive and (b) how to deal with unexpected technical issues. Their readiness might be explained by their attitudes towards online teaching, the knowledge and time available, and support for making online teaching more interactive for students. We also identified teachers who were ready for such sudden changes and had some ideas to make mathematics lessons interactive with online teaching.

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KEYWORDS
Online teaching of mathematics; teachers' mental readiness; theory of planned behaviour; anxiety; ideas for teaching

1. Introduction

In 2021, we face a world-wide pandemic caused by the COVID-19 virus, and in 2019 nobody would have imagined what we are experiencing now, including long school closures, with many pupils staying away from their schools and not receiving sufficient learning opportunities. After the school closures in March 2020, and the unstable situation in April and May, Japanese teachers were feeling a sense of crisis, giving rise to an urgent need to explore possible ways to provide the best educational opportunities for their pupils.

One of the solutions was to engage in 'online teaching and learning', which is now widely available thanks to technological developments including the Internet and video-conferencing tools in addition to existing Web 2.0 technologies (Selwyn, 2007). With Japan's reputation as a leader in technology, one might imagine that Japanese teachers

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have been using online technologies for some time, but, in reality, this is far from the case. Furthermore, the Japanese government does not yet have accurate information regarding what attitudes Japanese teachers and students have towards online teaching, to what extent teachers have the capability to teach online, what IT equipment each family has in order to engage online, etc. Only a small number of Japanese schools have experience of 'distance learning' (e.g. programming) involving specialists from outside schools, while both teachers and students are in school (e.g. Morishita et al., 2018).

The mathematics education community has been increasingly interested in online teaching for some time (Borba et al., 2016; Borba & Llinares, 2012). Among many elements related to online teaching, teachers' readiness and intentions to use new tools available to them are key for educational practice (Pierce & Ball, 2009). Such information is essential to establish effective online teaching environments or to design teachers' professional development. It is also important to know what might make teachers less ready to use online tools because, as Selwyn (2011) states, 'educational technologists should be engaging actively with the negative aspects of education and technology and exploring how best to withstand them' (p. 717).

The aim of this paper is to gain insights into how Japanese teachers were mentally prepared to engage with online teaching, in particular when they faced a sudden, unexpected and challenging situation caused by factors beyond their control (in this case, the COVID-19 pandemic). We conducted an ad-hoc survey of 207 teachers in elementary/junior high schools in Japan in April 2020. We focused on elementary/junior high school teachers (teaching children aged from 6 to 15 years old) as this age range covers compulsory education in Japan. We asked the following research questions:

- RQ1: Given the challenging and uncertain situation, how well were Japanese elementary and junior secondary school teachers mentally ready to use online teaching in mathematics?
- RQ2: What common/different concerns related to their mental readiness did elementary and junior secondary school teachers report?

We were interested in both common and different concerns in elementary and junior high school teachers. Whereas identifying common concerns is useful for understanding Japanese teachers' mental readiness in compulsory education holistically, differences might inform more tailored support and future actions for each school stage.

What we learnt from this study might be useful to reflect on what teachers might feel when they face a sudden change, and to consider how to support teachers' use of online teaching – a research area that still needs further exploration (Engelbrecht et al., 2020).

2. Online teaching in mathematics

While we acknowledge there are many different types and forms, in considering the current situation in Japan, we consider online teaching as educational activities entirely or partially using the internet (Carr-Chellman & Duchastel, 2000; Ko & Rossen, 2017), in particular:

- Synchronous, real-time teaching with video-conferencing tools such as Skype, Zoom and Google Classrooms;

- Asynchronous teaching using recorded video, voices, etc.;
- Use of structured learning with websites, online quizzes, PDFs, etc.

The studies of online teaching in mathematics are not new. For example, Quinn et al. (2015) evaluated their developmental process of an online course (13-week unit) for engineering students in Australia. From this study we can learn that developing an online mathematics course is a complex process, addressing issues around curriculum design, students' lack of technological skills, students' engagement, supporting staff preparation, infrastructure, etc. Such suggestions are further discussed by Borba et al. (2016), who conducted a literature survey from major mathematics education journals such as *Educational Studies in Mathematics*, *Journal for Research in Mathematics Education*, *For the Learning of Mathematics*, and *The Journal of Mathematical Behavior*. Five issues emerged as areas to be explored: (i) relationships between students and mathematical knowledge shaped by mobile technologies, (ii) the potential of Massive Open Online Courses (MOOCs) to affect access to and the quality of mathematics, (iii) how to organize and design online mathematics resources, (iv) design and use of online learning spaces for collaborations, and (v) teachers' use of blended learning (p. 660).

There are also studies into the effectiveness of online teaching in schools, including its assessment. For example, in the U.S., O'Dwyer et al. (2007) conducted an experimental study of an online teaching course for algebra in secondary schools. Students who attended the online programme had adequate access to technology and enjoyed learning algebra. These students gained knowledge and understanding well, whereas they felt less confident in algebraic skills compared to the students in face-to-face classes. They also felt the interactions between students and online teachers could be better.

Based on the data taken from teachers at the Open University of Catalonia, Badia et al. (2017) identified three approaches (the Content Acquisition approach, the Collaborative Learning approach, and the Knowledge Building approach), and suggest that teachers need to be aware of what roles should be adopted in online teaching, such as instructional design, managing social interactions, learning assessment, etc. In Stockholm, Hrastinski et al. (2018) identified challenges of online tutoring such as how to facilitate students' inquiry, how to support students' collaboration, and how to deal with emotions, etc. They found the use of digital badges might be useful to encourage online tutors to develop their skills.

Trenholm et al. (2015) surveyed assessment and feedback practices from 70 fully asynchronous online instructors in undergraduate mathematics in the U.S. As expected, this study revealed the complex nature of assessment and feedback in mathematics teaching. For example, instructors used a range of different assessment schemes with a de-emphasis on students' discussions and the implementation of non-invigilated exams. Instructors who used non-invigilated assessment tended to make use of more process-based feedback (providing hints or comments, challenging students' understanding), but they also found:

> no link between the quality of feedback used and participants' approaches to teaching for conceptual understanding and with a student focus, suggesting this feedback may not be, at least primarily, advancing student learning. (p. 1215)

These previous studies suggest that it is possible to deliver high-quality online teaching in mathematics provided that there are various careful considerations such as

teacher preparation, effective curriculum design, adequate infrastructure, clear teachers' roles, organized learning environments and resources, adequate social interactions and assessment. However, it seems that there is almost no study about teachers' intentions to use or try online teaching by participants who have had almost no prior experience. Our study aims to contribute to this aspect of online teaching of mathematics, by focusing on how Japanese teachers were mentally ready to take part in online teaching when they were faced with the sudden unexpected and challenging situation.

3. The theory of planned behaviour and anxiety about mental readiness to use online teaching

Implementing educational practice with new tools needs careful staff preparation (Quinn et al., 2015). Chua and Chua (2017), for example, conducted a survey with 320 school principals and senior assistants in Malaysia and found that their readiness to use ICT tools was one of the important elements of e-leadership practice in education, significantly related to organizational culture.

In this paper, we take the theory of planned behaviour (TPB) as a main theoretical idea. The TPB is a model to predict the intentions of human behaviours with attitude, subjective norm, and perceived behavioural control (Ajzen, 1991). The first element of the TPB, the attitude toward the behaviour, 'refers to the degree to which a person has a favorable or unfavorable evaluation or appraisal of the behavior in question' (Ajzen, 1991, p. 188). In our context, this element is related to teachers' attitudes towards students' mathematical understanding and thinking in classroom practice, which is central to mathematics education research (e.g. Goos & Kaya, 2020).

The second element of the TPB, subjective norm, 'refers to the perceived social pressure to perform or not to perform the behavior' (Ajzen, 1991, p. 188). By referring to studies such as Forgasz and Griffith (2006), Pierce and Ball (2009) considered whether Australian teachers' intentions to use new technologies might be affected by their colleagues, parents and guardians, etc. The school climate and trust within the institution is one of the key factors for the successful use of ICT (e.g. Albion et al., 2015). For example, newly qualified teachers in Japan might have to consider the expectations of their senior colleagues or teachers might be concerned if their colleagues considered that the use of online teaching could result in teaching mathematics superficially. Indeed, Japanese teachers are known to undertake Lesson study in their practice, and they have many opportunities to collaborate with other teachers (e.g. Takahashi & McDougal, 2016). Therefore, this social aspect which is related to teachers' intentions cannot be ignored.

The third element of the TPB, the degree of perceived behavioural control 'refers to the perceived ease or difficulty of performing the behavior and it is assumed to reflect past experience as well as anticipated impediments and obstacles' (Ajzen, 1991, p. 188). This element is related to teachers' knowledge, skills, availability of resources including time, costs for technologies and accessibility. (Pierce & Ball, 2009). In particular, Technological Pedagogical Content Knowledge (TPCK, e.g. Koehler et al., 2007) is a useful construct to conceptualize teachers' knowledge, for example, their knowledge about functions of particular tools for online teaching, or using such functions to enable interactions with students in online teaching.

Existing studies suggest that TPB can be a useful theory to explain pre-service teachers' and qualified teachers' intentions to use technologies in education. For example, Pierce and Ball (2009) found that while Australian secondary school teachers had positive attitudes towards the use of technological tools in mathematics, they also expressed concerns about the costs and values of such tools for increasing of student motivation towards learning. Sadaf et al. (2012) examined pre-service teachers' intentions to use Web 2.0 technologies in K-12 classrooms in the U.S. Through a survey ($n = 190$) and interviews ($n = 12$), they found the intentions were influenced by the beliefs informed by TPB, that is, behavioural, normative and control beliefs. Similarly, Cheon et al. (2012) reported that the three elements of TPB explained U.S. college students' acceptance of mobile learning.

Sniehotta et al. (2014) criticized TPB's validity and utility in health psychology and suggested it is 'time to retire' this theory. We do not consider TPB has to be retired yet, but some additional considerations outside the theory might be useful to understand teachers' readiness to use online teaching. For example, it might be expected that many teachers would be anxious about their abilities to implement 'good lessons' online. In addition to TPB, we also consider technological anxieties, which are negative feelings related to the use of (or considering the use of) technology in practice, for example, anxiety about using new tools might be related to the perceived use of new technological tools (Bailey et al., 2017). This aspect is particularly relevant to our study, as the current situation is one in which almost no teachers have formal experience of online teaching, but they want to make their lessons interactive and inquiry based (Hino, 2015; Stigler & Hiebert, 2009), which are also seen as important approaches in online teaching (Badia et al., 2017; Borba et al., 2016; Engelbrecht et al., 2020; Hrastinski et al., 2018) as well as content acquisition and knowledge building (Badia et al., 2017).

The TPB is not the only tool that can be used to study teachers' readiness to use new tools, programmes, etc. For example, Hung (2016) also investigated how 376 Taiwanese teachers-as-learners might be ready to take online learning (in-service training) with the Teacher Readiness for Online Learning Measure (TROLM) scale, and reported that four factors: communication self-efficacy; institutional support; self-directed learning; and, self-efficacy, are particularly related to readiness. Moreira-Fontán et al. (2019) also suggest that Spanish in-service students' autonomous motivation to use ICT tools is related to their self-efficacy and institutional support. Scherer et al. (2021) investigated the readiness for online teaching of 739 teachers in higher education from 58 countries, during the COVID-19 pandemic. They particularly examined how teacher profiles such as online teaching experience, gender differences, academic disciplines, contexts of the online teaching shift and culture might be related to readiness in addition to self-efficacy, institutional supports, and knowledge. This study identified three profiles (low readiness, inconsistent readiness, and high readiness). They also found 'gender, online teaching and learning experience, academic disciplines, and the days of preparing for the OTL shift explained differences in the probabilities of profile membership' (p. 12).

Our reason for taking TPB, and Pierce and Ball's ideas, is pragmatic. Pierce and Ball's (2009) study was conducted in mathematics education, and the question items include ones specific to the teaching of mathematics with ICT rather than the general questions which were used in many of the studies described above. Also, Pierce and Ball stated that TPB provides a quick and effective instrument for collecting teachers' perceptions (p. 314), and we were encouraged to use their survey questions as a starting point as we had to prepare

a survey for the sudden and challenging situation caused by COVID pandemic in April 2020. TPB also includes some question items related to self-efficacy, institutional supports, etc. We argue that the use of TPB is reasonable to fulfil the aim of our study.

4. Methodology

4.1. Survey

In order to collect data from Japanese teachers, we conducted an online survey between 9 and 20 April 2020, when they faced a quite unstable situation due to the COVID-19 pandemic. We opened the survey for a limited period as we wanted to capture teachers' perceptions at a time when the situation for education was particularly unpredictable and little in the way of information or official guidelines for online teaching were available.

The survey has three sections: Introduction and background questions (Q1), Perception questions (Q2), and Open questions (Q3). For Q1 and Q2, a five-point scale was used. In the introductory part, we explained the aim of the survey and outlined our definition of online teaching. Q1 asks background questions such as gender, school type, teaching experience, and information regarding the populations of the cities and towns where schools are located (To be clear, 'Q1:6' means Question [Section] 1, sub-question 6, as opposed to 'questions 1–6'.). This section also asks how participants feel about the internet connection in their schools (Q1:6) mental readiness for implementing online teaching (Q1:7), and their sense of crisis (Q1:8).

For Q1:7, the term 'kokoro no jyunbi 心の準備' was used to ask about their mental readiness as it is often used to ask or confirm to what extent you are ready to do something new, or radical, for example, before doing bungee jumping. This 'mental readiness' is our main outcome variable which we hoped would be explained by the items in Q2 and 3. For Q1:8, the term 'kiki-kan 危機感' was used. We have translated it here as 'sense of crisis', and it captures how worried teachers are about the current pandemic disruption, and how critical or urgent they perceive the educational problems that it throws up.

Q2 is the main part of the survey, consisting of 22 questions which are derived from previous studies (e.g. Pierce & Ball, 2009) as well as our general interests in the topic, summarized in Table 1. The first 12 questions are adopted from Pierce and Ball (2009), mainly asking about perceptions of online teaching in terms of the three factors of the TPB: attitude (AT), social norm (SN), and control behaviour (CB). Q2:13-16 ask about general interests and perception of the value of online teaching in attitudes (AT). Q2:17-19 ask questions related to their anxiety about being able to make their teaching with online platforms like their usual lessons (Anx). We included phrases such as 'ideal lesson' or 'similar to face to face', and lower scores represent their anxieties to use online teaching. These questions are also related to teachers' self-efficacy, i.e. 'One's assessment of one's own ability to complete a task successfully' (Hung, 2016, p. 123). We also added Q2:20 (assessment, AS), Q2:21 and 22 about expectations from students (SN). These questions are used as independent variables for the outcome variable (Q1:7).

Q3 asks if respondents have any ideas for future online teaching as well as giving them the opportunity to write any comments on the current situation, from which we hoped to collect more information about how Japanese teachers were feeling in terms of the situation caused by COVID-19. This question asks if they have ideas for making teaching via

Table 1. Question items in Q2.

Question items (Strongly disagree = 1, Strongly agree = 5)	Reference
Q2:1 If I use more online teaching, my students will undertake more mathematical activities or learning.	AT Active
Q2:2 It will be difficult for students to understand mathematics with ONLY online teaching.	AT Difficult with only online
Q2:3 If there are unexpected problems caused by technology, I will be able to manage to deal with these.	BC Unexpected problems
Q2:4 Online teaching can be used to help students gain a deeper understanding of math than is possible with face to face teaching.	AT Deeper understanding
Q2:5 I feel principal teachers or mathematics coordinator in my school expect me to use online teaching in my mathematics classes.	SN Expectations from senior colleagues
Q2:6 My colleagues think that when my students experience online teaching or learning, their learning might be superficial	SN Superficial learning (colleagues)
Q2:7 My students' parents/guardians think more online teaching for mathematics should be used.	SN Expectations from parents/guardians
Q2:8 With only using online teaching I will be able to cover all the required content in mathematics curriculum.	BC Covering curriculum
Q2:9 Online teaching provided in the current websites is too expensive for my students to access	BC Expensive or not
Q2:10 Using online teaching makes mathematics more enjoyable for my students.	AT Enjoyment
Q2:11 I will need to use my personal time to learn to use new technological tools for online teaching.	BC Use of personal time
Q2:12 In online teaching, it is possible for my students to engage with more real world problems.	AT Real world problems
Q2:13 I am interested in online teaching	I/V Interest
Q2:14 I consider online teaching will be widely used in schools as the use of it can be effective.	I/V Wide use in future
Q2:15 I am keen on trying online teaching if there will be technical support available.	I/V Keenness if support is available
Q2: 16 In whatever circumstance, I feel hesitant to use online teaching.	I/V Hesitance
Q2:17 In online teaching, I will be able to implement lessons which I consider will be 'ideal'.	Anx Ideal lesson
Q2:18 In online teaching, I will be anxious to interact with my students, like I do in face to face teaching.	Anx Interaction with students
Q2:19 If I use functions such as chat-box, whiteboard, etc. then I will be able to implement online lessons which will be similar to face-to-face lessons.	Anx Use of technological functions
Q2:20 It is easy to undertake assessment of students' learning gained by online teaching.	AS Assessment
Q2:21 I feel my students expect me to use online teaching in my mathematics classes.	SN Expectation from students
Q2:22 My students think that when they experience online teaching or learning, their learning might be superficial.	SN Superficial learning (students)

online 'dialogic and deeper for learning' which are currently recommended in the Japanese national curriculum.

These questions were proposed by two of the authors and discussed and agreed within the team who have all had extensive research experience in mathematics and technology education research. One of the authors is an expert in distance learning in Japan (at a higher education level). Since our aim is not to propose a confirmatory model of teachers' perceptions, we felt this process was sufficient to validate the survey questions.

4.2. Sampling process and participants

After we prepared a first draft of the survey on an online (Google) form, on 9 April 2020, we initially contacted teachers with whom we had previously worked in order to carry

Table 2. Participants information.

Schools	Variables	Frequency
Overall $N = 207$	Male	153 (73.9%)
	Female	54 (26.1%)
Elementary school teachers (students ages from 6 to 12) $N = 105$	Male	65 (62%)
	Female	40 (38%)
Junior high school teachers (students ages from 12 to 15) $N = 102$	Male	88 (86.3%)
	Female	14 (13.7%)

Table 3. Teaching experience and school sizes.

Schools	Variables	Mean	SD	Range
Overall $N = 207$	Years of teaching experience	11.96	9.26	0–40
	Number of students	449.67	252.78	7–1500
Elementary school teachers (students ages from 6 to 12) $N = 105$	Years of teaching experience	11.5	8.82	0–37
	Number of students	479.63	245.86	23–1400
Junior high school teachers (students ages from 13 to 15) $N = 102$	Years of teaching experience	12.4	9.7	0–40
	Number of students	418.82	257.27	7–1500

out a 'pilot'. Nineteen teachers in elementary/junior high schools responded and we asked them for their feedback, receiving no radical comments on the survey questions in general. After this, only small typographical errors were corrected, and the survey was announced on social networking sites such as Facebook. We emailed more teachers using snowball sampling. We acknowledge this method has certain limitations such as the sampling population size is not known but considering the urgent circumstances both we (researchers) and the participants (teachers) had to face, we consider this was the best option to collect data as much as possible. The survey was open until 20 April 2020. Research ethics was approved by Hokkaido University of Education (ref: 2020041001). A consent form statement was also included in the survey page.

In total, 207 teachers in elementary/junior high schools kindly participated in the survey and gave full answers which can be used in data analysis. Tables 2 and 3 summarize the participants' background information.

Overall, more male teachers participated in the survey in junior high but more female teachers in elementary schools, which is consistent with the current gender distribution of mathematics teachers in Japan. The mean average of teaching experience for our survey participants was about 9–12 years, indicating a wide range of teaching experience (SD 9.26). The school sizes varied widely, as do the standard deviations and ranges of the numbers of students in their schools. Looking at the participants' profiles, we must be cautious as to whether the findings presented in the following sections would represent the general views of Japanese teachers about online teaching. However, we believe our data contain interesting and complex views which Japanese teachers (who participated in the survey) had at the time.

4.3. Data analysis

The answers were analysed immediately after we closed the survey. First, we checked any missing values and confirmed all data could be used for the analysis. This paper aims neither to confirm a conceptual model nor to construct a valid measurement for Japanese teachers' perceptions of online teaching of mathematics. Thus, our analytic approach was explorative, iterating different statistical analysis and examinations of statements from free text questions (Q3).

In order to assess teachers' mental readiness to use online teaching, we first provide a descriptive analysis of the survey result (section 'Overall results'). We then took two approaches (see sections on 'Multiple regression analysis' and 'EFA and LRA'). In a multiple linear regression analysis, we identified what variables might explain the outcome variable (Q1:7 mental readiness to implement online teaching). We used multiple linear regression analysis based on our theoretical assumptions that certain degrees of teachers' mental readiness might be explained by factors such as their attitudes, social norms, behavioural control, and anxiety. We provide results from elementary and junior high school separately in order to illustrate the common/different concerns about online teaching that elementary and junior secondary school teachers held.

Explorative factor analysis (EFA) and latent rank analysis (LRA) were used to classify the types of teachers, and to examine any relationships between Q1:7 and factors in elementary and junior high school teachers, focusing on common concerns observed from both elementary and junior high school teachers. For EFA, we iterated EFA with maximum likelihood and the Promax rotation. During each iteration, items with factor loading scores less than 0.3 or causing lower Cronbach values were removed. We used this technique in order to uncover underlying factors which might exist in Japanese teachers' mental readiness to use online teaching. In this iteration, we mainly used SPSS ver. 26.

Finally, we used latent rank analysis (LRA), which is a relatively new approach developed by Japanese researcher, Dr Shojima (2008). Fundamentally, LRA is based on self-organizing (SOM) (e.g. Kohonen, 2001) and generative topographic mapping (GTM) (e.g. Bishop et al., 1998) approaches, mapping multi-dimensional data to a uni-dimensional ordinary space by putting 'similar' cases together in terms of their ranking within a group. This technique requires complex computations and steps, but Japanese researchers have developed computation programmes that enable us to conduct this analysis (Exametrika or a function package LRA for R (ver 4.1) from http://bit.ly/latent_rank). We used R with the function package. This was carried out to find 'latent' relationships which might be hidden in our data and which can be used to divide our participants into several groups and to see what characteristics each group might hold. Finally, we examined each group's mental readiness.

5. Findings

5.1. Overall results

Figure 1 summarizes the mean scores from Q1:6 (internet connection), Q1:7 (mental readiness), Q1:8 (sense of crisis) and Q2.

The participants' mental readiness has a mean of 2.42, but their sense of crisis was very high (4.57) with a narrow SD (0.72). The results indicate that the overall tendencies of each school teacher are very similar (and t-tests further suggest that there are no items

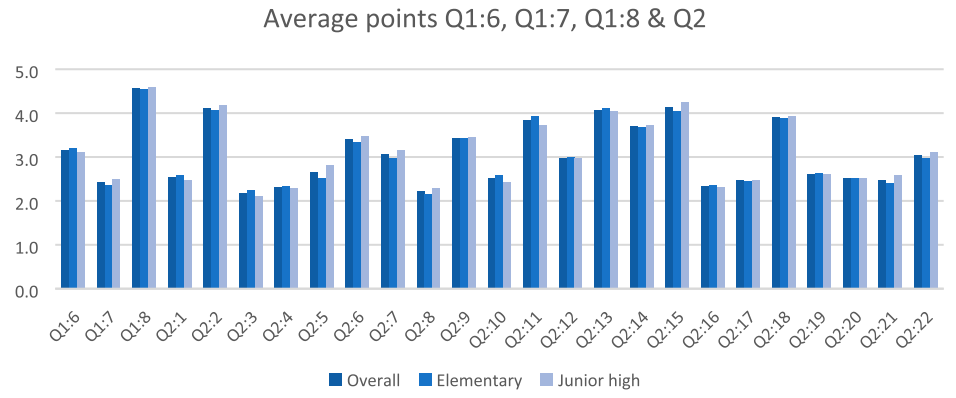

Figure 1. Mean scores for Q1:6, 1:7, 1:8 and Q2.

that show statistically significant differences between elementary and junior high school teachers in the mean scores for Q1:6, 1:7, 1:8 and Q2). No correlations of more than 0.3 between these questions and teachers' experience/sizes of schools were recognized, indicating the situation might affect teachers' mental readiness and sense of crisis regardless of their experience and school size. Both elementary and junior high school teachers were interested in online teaching in mathematics (Q2:13 mean 4.08), and if there was support available, they were keen on trying to deliver it (Q2:15, mean 4.14). They were also not hesitant to use this approach (Q2:16, mean 2.33), and in future many believed that online teaching would be widely used (Q2:14, mean 3.70). Therefore, they have relatively positive attitudes towards online teaching. On the other hand, it is not surprising that they feel face-to-face teaching is necessary for understanding of mathematics (Q2:2, mean 4.12), lack of confidence to deal with unexpected technological difficulties (Q2:3, mean 2.17), anxious about interactions with students (Q2:18, mean 3.90), etc. Also, they felt that they have to use their personal time to prepare online teaching (Q2:11, mean 3.83). Also, only 37% ($N = 77$) of the participants had some ideas for making online teaching 'dialogic and deeper for learning' ('dialogic' here is a word used in current policy documents in Japan, indicating making teaching more interactive through dialogues in classrooms).

5.2. How might teachers' mental readiness be explained? – multiple regression analysis

The overall results revealed how Japanese teachers might be feeling about the situation in terms of online teaching of mathematics, with a high sense of crisis but relatively low mental readiness. We further explored how their mental readiness might be explained, and conducted multiple regression analysis, Q1:7 (1–5 scale) as outcome variable. We used a stepwise approach to specify significant items from possible independent variables Q1:6 (internet connection), Q2:1-Q2:22, and Q3 (Ideas for teaching) as (1; 0) = ('Yes I have ideas for teaching'; 'No'). Suggested best models are summarized in Table 4 as follows for each school (multi-collinearities were not identified in each model).

Considering the nature of our sampling, we do not claim these are the definite models for explaining teachers' mental readiness for using online teaching for mathematics. We

Table 4. Regression models for each school.

Model	*b*	SE *b*	Beta	*t*	Sig.
Elementary school teachers					
Q2:3 BC Unexpected problems	0.413	0.086	0.367	4.801	0.000
Q2:5 SN Expectations from colleagues	0.318	0.075	0.326	4.215	0.000
Q2:11 BC Use of personal time	−0.2	0.075	−0.190	−2.665	0.009
Q3:1 Ideas for teaching	0.515	0.191	0.186	2.699	0.008
Q1:6 Internet connection	0.140	0.076	0.131	1.834	0.07
Adjusted $R^2 = 0.523$					
Junior high teachers					
Q2:3 BC Unexpected problems	0.228	0.094	0.216	2.429	0.017
Q2:5 SN Expectations from colleagues	0.304	0.088	0.313	3.451	0.001
Q2:11 BC Use of personal time	−0.227	0.084	−0.231	−2.71	0.008
Q2:13 AT Interest	0.292	0.111	0.225	2.636	0.01
Q2:7 SN Expectations from parents/guardians	−0.203	0.108	−0.163	−1.87	0.065
Q1:6 Internet connection	0.191	0.108	0.152	1.773	0.079
Adjusted $R^2 = 0.331$					

are aware that the *p*-values of some items are more than .05. However, we found some interesting relationships between their mental readiness and their perceptions of online teaching, summarized as follows:

- For elementary school teachers, the adjusted R^2 is 0.523, suggesting about 52% of the variance was explained by Q2:3 (Unexpected problems), Q2:5 (Expectations from senior colleagues), Q2:11 (Use of personal time), Q3:1 (Ideas for teaching), and Q1:6 (Internet connection).
- The junior high school teachers' model is similar – Q1:7 (Mental readiness) might be explained by Q2:3 (Unexpected problems), Q2:5 (Expectations from senior colleagues), Q2:11 (Use of personal time), Q2:13 (Interest), Q2:7 (Expectations from parents/guardians) and Q1:6 (Internet connection), but the adjusted R^2 is 0.331. This relatively low R^2 for junior high school teachers suggests that there will other factors than those identified in our survey items.
- There are slight differences, e.g. in elementary schools, ideas for online teaching (Q3:1) might be related to their mental readiness, and for junior high schools, their own interest in online teaching (Q2:13) and expectations from parents/guardians (Q2:7).

These regression models do not explain everything. More than 40% and 60% of the variances for elementary and junior high school were not explained by the survey questions.

Reflecting on these findings, we have examined free-text comments provided by the teachers from elementary and junior high school teachers. First, we are very struck by teachers' sincere sympathies towards students and their development. Reading through these comments, we speculate that elementary school teachers might also be especially concerned for their pupils' mental health, represented by 'kokoro no ke-a 心のケア (a direct translation is "caring for the mind")' or home environment/circumstances in family ('katei kankyo 家庭環境') (a direct translation is 'home environments'), while for junior high school teachers, gaps in students' attainments in mathematics ('gaku-ryoku 学力'), which might be caused by unequal educational opportunities, were highlighted. Table 5 shows some of the examples of teachers' voice related to these aspects.

Table 5. Comments by teachers in elementary/junior high schools.

School	Example comments
Elementary schools	• In March when I visited to my students while my school was closed, I felt there are many children who are just playing games, unhappy with their home environment, having no contacts with their friends, etc. and I think caring for their mental health is necessary in addition to supporting their academic learning. • I really hope this will end soon, but I felt children seem to be very tired, facing a situation which we have never experienced. In addition to securing their academic attainment, it is necessary to care for their mental health. • Children are very stressed by staying at home for a long time. I think it is particularly difficult for children who have special needs to get back to normal as their life routine has been really disturbed. • I consider the most important thing is caring for children's mental health. It is certainly important to understand the current crisis, but there is too much information around us. Children who are taking in all this information have more anxieties than adults. In fact, I have heard several children are crying in the night as they cannot go to school, news about COVID-19, etc. I also think, because of the current situation, we need to alter our ways of thinking, not following 'what we did before … '. We need to do what we can do as much as possible, and with available resources. Change our point of view. We need to try new things and not keep just thinking to try to revert to what we normally did (before the pandemic).
Junior high schools	• I think the gaps in students' attainment will be wider in particular between students who can study by themselves and not. • There will be insufficient understanding of mathematics topics, and educational opportunities of interactions with others will be reduced. I am concerned that students might not fully develop useful knowledge as well as their emotional intelligence. To be honest, I really worry if I can manage to cover all the curriculum content. • I worry how my students are spending their time, and I think they feel very anxious as we do not know when this will end. I also worry their attainment gaps will be wider. • There are ideas to increase our lessons from 6 to 7 in a day when schools are open, but I do not think simply increasing lesson hours will be a solution to develop students' attainment. I also worry we might have to reduce and restrict school events so that some cultural aspects which are unique to each school might be lost.

5.3. Teachers' mental readiness for online teaching – EFA and LRA

So far, the results in the previous sections suggest that both elementary and junior high school teachers had similar concerns about online teaching when they faced the challenging situation caused by the COVID-19 pandemic in early 2020. In order to complement our results from the multi regression analysis, we conducted EFA and LRA by focusing on Q2:1 – Q2:22. In this analysis, we put the data from elementary and junior high school teachers together, as their responses, in general, were very similar.

Overall the Cronbach alpha value is 0.795 (the negative items were reversed), the Kaiser-Meyer-Olkin measure of sampling adequacy was 0.804, and Bartlett's test of sphericity was significant ($\chi^2(231) = 1178.475, p < .000$). These figures suggest that it is possible to conduct a factor analysis. We then iterated to identify how it would be reasonable to describe the perceptions with the three factors with 15 items, summarized in Table 6.

The three factors explain about 52% of the total variance of the data. The correlations between the three factors are between 0.361 and 0.45. The overall Cronbach's alphas were 0.819, and 0.785 on the first factor, 0.798 on the second factor and 0.638 on the third factor. We conclude that these three factors are reasonable, although the third one's alpha is a little bit low. More importantly, we can interpret the first factor as 'Attitude and anxiety towards online teaching', the second factor as 'Interests and values', and the third factor as 'Subjective norm in online teaching'. Of course, this three-factor model is just one possible solution to how to interpret the underlying factors.

Table 6. Factors for elementary/junior high school teachers.

	Factor 1 $\alpha = 0.785$	Factor 2 $\alpha = 0.798$	Factor 3 $\alpha = 0.638$
Q2:10 AT Enjoyment	**0.667**	−0.068	−0.167
Q2:17 Anx Ideal lesson	**0.664**	0.059	−0.008
Q2:2 AT Difficult with only online	**0.56**	−0.113	−0.04
Q2:4 AT Deeper understanding	**0.557**	−0.014	−0.004
Q2:18 Anx Interaction with students	**0.552**	−0.032	0.113
Q2:1 AT Active	**0.533**	−0.038	0.152
Q2:12 AT Real world problems	**0.496**	0.215	0.026
Q2:19 Anx Use of functions	**0.369**	0.172	−0.008
Q2:15 AT Keenness if support is available	−0.179	**0.915**	−0.018
Q2:13 AT Interest	−0.067	**0.839**	−0.015
Q2:16 AT Hesitance	0.118	**0.568**	−0.029
Q2:14 AT Wide use in future	0.249	**0.529**	0.014
Q2:7 SN Expectations from parents/guardians	−0.044	−0.061	**0.706**
Q2:21 SN Expectation from students	−0.003	0.105	**0.686**
Q2:5 SN Expectations from senior colleagues	0.012	−0.07	**0.516**

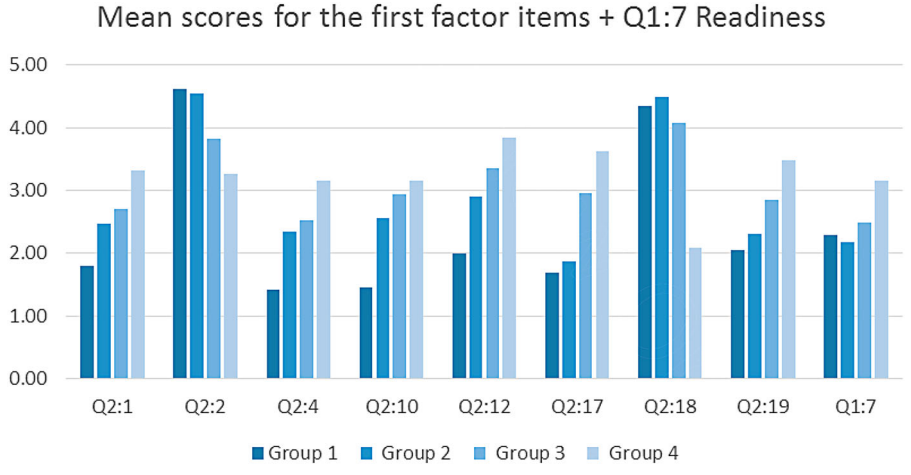

Figure 2. Mean scores in ranked groups.

We then experimented to use the LRA for the first factor (eight items) extracted in the above section. We were motivated because one of the Japanese teachers' main concerns is how they plan and implement actual mathematics lessons, we felt we might be able to find some 'hidden' ordinal pattern from the data, which might be related to the mental readiness for elementary and junior high school teachers. As we stated, the LRA is an approach to identify such latent ranks in a data set (one factor is assumed) based on SOM and GTM, and we applied this approach to the first factor. The suggested procedure is first to determine how many ranks might exist (mainly referring to the lowest AIC), divide the data set into sub-groups, and then explore what characteristics each group has.

As a result of the LRA, four groups were suggested in accordance with the participants' responses to the eight questions, and each item's mean averages in ranked groups and their mental readiness (Q1:7) are summarized in Table 7 and Figure 2. (N.B. the negative items are reversed, and higher scores indicate respondents being more positive towards online teaching).

Table 7. Mean scores in ranked groups.

	Q2:1	Q2:2	Q2:4	Q2:10	Q2:12	Q2:17	Q2:18	Q2:19	Q1:7
Group 1 ($N = 43$)	1.81	4.63	1.41	1.45	2.00	1.69	4.35	2.06	2.28
Group 2 ($N = 71$)	2.47	4.54	2.35	2.56	2.89	1.88	4.49	2.30	2.18
Group 3 ($N = 67$)	2.71	3.82	2.52	2.94	3.35	2.95	4.08	2.85	2.48
Group 4 ($N = 26$)	3.32	3.27	3.16	3.16	3.84	3.62	2.09	3.48	3.15

What these results might indicate is that there are potentially four groups in our participants from elementary and junior high schools, and they might be described as follows:

- Group 1 (N = 43, 18 elementary and 25 junior high): Teachers in this group have relatively low mean scores for all the items in factor 1 'Attitude and anxiety in online teaching', indicating they are quite anxious about implementing mathematics lessons online. The mental readiness score was relatively low (2.28). 30.2% of the teachers in this group stated they have how to enable their teaching dialogic (Q3:1).
- Group 2 (N = 71, 32 elementary and 39 junior high): Teachers in this group also had anxieties, but their attitudes towards Q2:4 (Deeper understanding), 10 (Enjoyment), and 12 (Real-world problems) are a little higher than the group 1 teachers. However, their mental readiness is quite similar to those in group 1. 33.8% of the teachers in this group stated they have ideas how to enable their teaching dialogic (Q3:1).
- Group 3 (N = 67, 44 elementary and 23 junior high): Teachers in this group have a bit more of a positive attitude towards Q2:2 (Difficult with only online) and Q2:17 (Ideal lessons) as well, but still feel anxious about interactions with students in online teaching. Their mental readiness is still 2.48 on average. 32.8% of the teachers in this group stated they have ideas how to enable their teaching dialogic (Q3:1).
- Group 4 (N = 26, 11 elementary and 15 junior high): Teachers in this relatively small group felt relatively positive about online teaching including Q2:18 (Interactions with students, lower scores mean more positive toward interaction with students with online environments). 65.4% of the teachers in this group stated they have ideas how to enable their teaching dialogic (Q3:1).

Interestingly, group 4's mental readiness (mean = 3.15) is higher than the other groups. In fact, a one-way ANOVA suggests that this group's readiness is statistically higher at least than groups 1 and 2 ([$F(3, 203) = 4.014, p = .008$]), which indicates supporting interactive lessons for elementary and junior high school teachers is one of their urgent concerns. The mean averages of teaching experience of each group are 13.66 (SD = 9.14), 9.65 (8.7), 12.75 (9.6), and 13.42 (9.2) respectively, and there is no significant difference among these groups. This indicates that teachers' mental readiness for trying online teaching might be related to 'Attitude and anxiety towards online teaching', for example how to make their teaching interactive (Q2:18) with online situation.

One might argue that the results were somehow expected, i.e. teachers were very anxious and their primary concern was how to make their lessons possible in online situation. Although we acknowledge such a concern, another interesting fact was revealed by the LRA in relation to Q3:1. We have stated that only 37% of the participants had some ideas for making online teaching 'dialogic and deeper for learning' (Q3:1) This was not evenly

Table 8. Ideas for making their teaching dialogic in online teaching.

Group	Example comments
Communication (51% of the stated ideas)	• We need to improve both the hardware and software skills for two-way interaction between teachers and students, and between students and students, so we need training for this. (G1) • Chat (G1) • Create a system where children can also interact with each other online through a screen. (G2) • Skype (G2) • It is important to create an environment where people can talk freely with different people without having to move from one seat to another. (G3) • Smaller groups for quick chats (G3) • Easy online grouping and on-screen discussions. (G3) • In our school, we use google classroom and zoom to share questions from students and take time to think together (G4) • By using two ways communication apps such as Loilo note, I consider we can realize and maintain the same level of face-to-face teaching in classrooms (G4)
Assessment (20%)	• Questionnaire (G1) • We need a system that allows us to clearly see the children's responses. We also need a system that allows us to answer the questions carefully. (G1) • A student's answer in their submitted work could be fed back to the whole class and they could be asked to summarize their thoughts on the answer. (G2) • Setting up a question box and an answer or hint box on the web. (G2) • We need to create an environment where we can see processes of children's thinking and where we can discuss from special to more general cases. (G3) • The solution process and utterances of each child will be recorded in the chat and other media, so that there will be an opportunity for discussion in accordance with the solution process. (G4) • The children's ideas, solutions and inspirations are shared interactively with all members of the class at all times via the chat and note-sharing functions. (G4)
Sharing (19%)	• Briefly show everyone what will be discussed. (G1) • Letting children write and share their work using the screen (G2) • Google Docs and Google Spreadsheets could be used to collaboratively fill in worksheets and share opinions on a single issue in real time. (G3) • Make it easy for the person in front of you to understand, so that ideas can be easily guided. (G4) • To prepare a more interactive environment. Also, to share figures and formulas in such a way that they can be easily understood by everyone taking part. (G4)

distributed across the groups. While about 30-34% of groups 1–3 had ideas, in group 4, 65.4% of the teachers answered in their responses to Q3:1 that they had ideas for making their teaching dialogic and deeper for learning with online environments.

Table 8 summarizes some of the ideas stated by the teachers (G1 = Group 1, etc.), which are roughly classified into four broad categories: (1) 'Communication' (accounting for about 51% stated ideas, and relating to supporting students' interactions during online teaching), (2) 'Assessment and Feedback (about 20%, including ideas to enable teachers to see students' thinking processes in order to provide assessment and feedback), (3) 'Sharing (19%, suggesting ways to support students to share their ideas) and (4) 'Others' (10%).

These teachers had already started exploring and trying out some possible ideas when they faced the sudden change in circumstances in March-April 2020 (please note the comments and ideas given in the responses to our survey are relatively short, but when this survey was done, almost no teachers had any experience of online teaching). All groups ideas are relatively similar, but compared to some Group 1 teachers who provided a short answer such as 'Chat', 'Skype', 'Questionnaire' etc., Group 3 or 4 teachers tend to provide a longer answers for their ideas with some specific names of tools such as 'Google doc' or

'Loilo note'. Consequently, they were more mentally ready for adopting online teaching (Q1:7). The lack of some concrete ideas or finding specific tools made some teachers more anxious to adopt online teaching in mathematics.

6. Discussion

The sudden and unstable circumstances caused by the COVID-19 pandemic in 2020 forced us to rethink how educational opportunities can be provided even after schools are closed. One of the solutions is to use online platforms for teaching and learning, and, in this study, we aimed to gain insights into how Japanese teachers were mentally ready to take on online teaching, in particular when they faced the sudden unexpected and challenging situation. We explored the following two research questions:

- RQ1: Given the challenging and uncertain situation, how much were Japanese elementary and junior secondary school teachers mentally ready to use online teaching in mathematics?
- RQ2: What common/different concerns related to their mental readiness did elementary and junior secondary school teachers have?

By answering the RQ1, the results from the descriptive analysis suggest that Japanese teachers had relatively positive attitudes towards the use of online teaching of mathematics, but their mental readiness in terms of using the online teaching was not high, and their sense of crisis was very high. Respondents' main concern was, as expected, how to make their online teaching interactive. In undergraduate mathematics education or online tutoring, online communication and collaboration have already been flagged as one of the issues needing to be tackled (Borba et al., 2016; Engelbrecht & Harding, 2005; Hrastinski et al., 2018; O'Dwyer et al., 2007). Our data showed Japanese elementary and junior high school teachers are also concerned with this aspect which is probably reasonable as they appear to prefer interactive, and problem-solving-based lessons in mathematics (Hino, 2015; Stigler & Hiebert, 2009). EFA and LRA (Shojima, 2008) were useful to give us a way to identify what kind of teachers would be more mentally ready to adopt online teaching, and what aspects particularly related to educational practice (extracted by EFA, factor 1) in their readiness. As we have shown in Table 7 and Figure 2, the teachers can be divided into the four teachers, and Group 4 teachers who had less anxiety towards making their teaching interactive in online teaching might be more ready to adopt new ways of teaching in this unstable situation. More than 65% of these teachers could provide ideas to make their teaching interactive in terms of 'Communication', 'Assessment', and 'Sharing'. In other words, in addition to relatively positive attitudes and ideas to use new technological tools, these teachers' self-efficacy in adopting online teaching might be higher than others, and this finding also echoes Hung (2016) and Moreira-Fontán et al. (2019) who found that self-efficacy is highly related to readiness/autonomous motivations to use ICT tools in education.

In answering the RQ2, based on our analysis of data from 207 teachers, we tentatively conclude that both elementary and secondary school teachers had similar concerns. In the context of mathematics education, TPB (e.g. Ajzen, 1991; Pierce &

Ball, 2009) and anxiety (Bailey et al., 2017) are useful constructs to explain teachers' mental readiness. Their readiness is partially explained by their attitudes towards online teaching (attitude towards behaviour), expectations from colleagues (subjective norm), dealing with unexpected problems, knowledge and time available (behavioural control).

These findings echo existing studies into the readiness/intentions to use technologies in education (e.g. Cheon et al., 2012; Sadaf et al., 2012). Also, concerns about institutional support, e.g. internet connections, dealing with unexpected problems, colleagues' expectations and time pressures might affect how much support the teachers felt they were receiving, a point that has been made before (Hung, 2016; Moreira-Fontán et al., 2019).

In terms of differences, elementary school teachers might be more concerned with pupils' mental status caused by the school closure, and junior high school teachers seemed to be more worried about gaps in students' attainments in mathematics. We, of course, acknowledge that these findings might be limited to teachers who are sufficiently interested in online teaching to be willing to participate in a survey. Our findings also suggest that more consideration should be taken into account, for example, related to bridging academic attainment gaps in mathematics.

7. Conclusion

In summary, although our findings are in line with those from existing studies, our study is one of the first to provide reasonable explanations for what Japanese teachers in mathematics were concerned with when they were faced with the unexpected situation caused by the COVID-19 pandemic. Also, our study can provide more domain-specific accounts of the teachers' concerns in online teaching in mathematics by using TPB and anxiety, rather than the general views about the use of ICT in education examined in previous studies (except Pierce & Ball, 2009).

COVID-19 made us think that we might have to radically change forms of education. Considering this is one of the first studies that has explored actual school teachers' view (not pre-service teachers for example) we believe that our findings contain worthy information which will be useful for future studies to explore reliable measurements of teachers' mental readiness for online teaching in mathematics, and other disciplinary areas such as science. Also, as we have seen, LRA can provide a powerful method to reveal participants' latent perceptions beyond a descriptive, superficial interpretations of the questionnaire results, and identify teachers who had positive attitudes and ideas for online teaching among the teachers with high anxieties when faced sudden, unexpected situation.

Reflecting on such views expressed by the teachers, it is necessary to organize and prepare consistent and sustainable technical support for online teaching so that they feel less anxious about the use of the various technical tools (Selwyn, 2011). In particular, rather than just suggesting 'use online tools for communication', we need to share an example of good practice, and examine which 'specific' tools can be used to support online communications, and sharing various ideas presented by students during online teaching, and how we can provide effective feedback for students' learning. It is also important to ensure that senior leaders of schools should be supportive, as this factor also had a significant impact on teachers' readiness in our data (Hung, 2016; Moreira-Fontán et al., 2019).

For classroom practice, it is necessary to devise several examples of mathematics lessons in an online format, in which teacher/students and student/student interactions might be possible. Such materials might show what teachers' roles and mathematical activities could be designed, how these interactions might appear, and how these interactions might be more effective, all of which would support online teaching suggested by previous studies (e.g. Badia et al., 2017; Engelbrecht et al., 2020; Hrastinski et al., 2018). Also, in relation to junior high school teachers' concerns about attainment gaps, we need more robust evidence as to whether the attainment gaps might be widened (or not) with online teaching compared to face-to-face teaching.

Our approach has a certain limitation in its rigour, that is, sampling and survey questions. It is necessary to revise question items, for example, asking teachers about their concerns about students' attainment in mathematics with online teaching. Also, other important factors such as self-efficacy, institutional support, and online teaching preparations, should be integrated more explicitly into subsequent studies in which a confirmatory factor analysis could be used. Also in 2021 Japan is still facing challenging situation and potentially forced to move to online teaching due on-going pandemic, we need to explore questions such as 'How will teachers' awareness of online teaching in 2021 change through online teaching?' or 'What are the challenges of providing quality online teaching?', which is essential to further explore teachers' perceptions of adopting online teaching in mathematics.

Finally, we do not claim that our findings describe a definite view of Japanese teachers' mental readiness for using online teaching in mathematics, but we hope to have shed light on just one aspect of their perceptions which was revealed by the survey questions based on TPB. These weaknesses were due to urgent and limited time for designing and conducting the survey, motivated by the COVID-19 pandemic.

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Data availability statement

Data from 207 teachers and R codes can be obtained from https://doi.org/10.6084/m9.figshare.17159129.v1

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