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RESEARCH REPORT

Do STEM teachers have the potential to become leaders in online education?

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Abstract

In 2022, the Taiwan Network Information Association found that 74.10% of distance teachers would rather not teach remotely after the pandemic. STEM teachers should be comfortable using technology in the classroom, and they seemed to enjoy online teaching. We can better understand STEM teachers' transition from face-to-face (FTF) to online teaching due to the COVID-19 pandemic, how they responded, and what changes were made. Case studies determined how well they responded and what changes were needed. Taiwan's science teacher and maker communities volunteer online. Nine Taiwanese STEM teachers were interviewed using modified Sintema questions (2020). Interviews took three steps. "#1 preparation time," "#2 early phase," "#3 late phase," and "#4 resumption of face-to-face teaching" were the data stages. STEM teachers' skills fall into three categories: pedagogical content knowledge, computational thinking, and self-efficacy, according to research. This study compared all changes in STEM online teaching method and characteristics to those before large-scale online teaching. We found that teachers had more issues than STEM ability, including "equipment," "student motivation," "class management," and "increased workload" (MOOCs). Lack of "FTF discussions" among STEM teachers during research caused unexpected issues. This difficulty may affect soft skill development. The study also found that STEM teachers face complex and varied challenges and that their online teaching experiences can be useful for other teachers.

Keywords: *Characteristics of STEM teachers, on-line teaching, STEM teacher*

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The outbreak of a new respiratory disease was confirmed for the first time in Wuhan, Hubei Province, PRC, at the end of 2019, and the virus had spread to Taiwan by January 2020 (Cheng et al, 2020). In addition to Taiwan, this outbreak of COVID-19 epidemic has caused an unprecedented large-scale suspension of normal school operations in many countries around the world. Countries are being forced to convert face-to-face (FTF) courses to online teaching in a very short period of time, and Taiwan has also been suspended entirely due to the threat of the epidemic.

In 2012, the National Research Council highlighted the importance of STEM education (National Research Council, 2012) as a subject that spanned multiple disciplines. It included science, technology, engineering, and mathematics. There were no teachers who specialized in STEM. They have superior information skills and more cross-disciplinary experience than all other teachers (Lewis, 2005; Schmid et al., 2021). STEM teachers would need to be familiar with the use of technology in the classroom and in fact they appeared to find online teaching very simple and natural. However, there were several challenges that had to be overcome in online teaching such as practice, creativity, and inquiry. As a result, we have an opportunity to get a clearer idea of the challenges that STEM teachers faced as they transitioned from FTF to the online teaching precipitated by the COVID-19 epidemic, how well they were able to respond, and what changes were implemented. The challenges faced in other fields are a subset of those faced by STEM teachers. This means that if it is possible to help STEM teachers overcome the challenges of online teaching, other teachers should easily be able to do the same. As an outcome, by investigating the breakthroughs in STEM teachers' online teaching dilemmas, it should be possible to provide a reference for other subjects' online teaching.

Theoretical Framework

The conundrum of urgent online education

Even in the face of mandatory distance learning during COVID-19 pandemic, higher education, which is the easiest country to adopt online teaching, is still plagued by technical and equipment issues, and the vast majority of students are unable to study online. The study also found that the problem of online teaching in rural areas is a lack of adequate network and equipment, and that the inability to have a suitable independent learning space has also caused problems in online learning. These problems made online learning difficult, and the social class divide has widened as a result of this situation (Verma et al, 2020). The unequal distribution of Information and Communications Technology (ICT) and the digital capability gap has exacerbated social inequality. Many technology companies offer educational discounts or assistance, providing services such as Google Classroom and Google Meet. However, this does not solve the most difficult aspect of online learning which is a lack of basic network equipment

and fast and reliable network connection (Dhawan, 2020). Computers and other forms of communication equipment are the most basic requirements for online education, and most countries were unprepared for online teaching in these areas.

Despite the fact that many countries have long attempted to integrate technology into the higher education system, most schools are scrambling to find coping strategies after COVID-19 has been in place for a long time. Teachers began to take online teaching seriously after a period of time. Learn how to teach online on topics that may be covered throughout the semester (Donitsa-Schmidt & Ramot, 2020).

Ali (2020) used a meta-analysis methodology to examine the impact of higher education closures during the COVID-19 pandemic. The study found resources, staff readiness, teacher confidence, student accessibility, and motivation, to be the critical factors in the implementation of online teaching. Serhan conducted a study involving 31 students from a university in the United States and found that the most difficulty encountered by both teachers and unprepared students was the conversion from FTF interaction to Zoom distance exchanges. Students were dissatisfied with their learning experience, teachers were unfamiliar with the new platform, and many users encountered technical difficulties, such as poor internet connectivity. The main disadvantages of using Zoom, according to students, were easy distraction, poor interaction and feedback quality, poor quality content, and technical difficulties (Serhan, 2020). Many distance learning studies use students' perspectives to investigate how students feel. Aside from students, the teacher plays an important role in the teaching field. In the face of significant changes in the teaching situation, the teacher's teaching method influences students' learning. How should teachers respond to online learning? How teachers adapt their teaching strategies will have an impact on teaching and learning in the post-epidemic era.

The Problem of STEM Course Online Teaching

With the exception of courses that require practice, such as science, teachers in Israel have successfully converted FTF courses to online courses. (Donitsa-Schmidt & Ramot, 2020). According to current researches (Adnan & Anwar, 2020; Polat, 2022; Zainal et al., 2022), when online teaching is unavoidable, some disciplines face some challenges and continue to study. The course's quality, as well as the development of different literacy in the same subject, will present unique challenges (e.g. creativity, technical implementation). As a result, it may be more appropriate in online teaching to analyze the literacy that needs to be developed in the subject.
Chen et al. (2020) discovered that students with more mythological concepts dropped out at the beginning of an online MOOC astronomy course in the United States. Amunga's (2021) literature analyzed during the epidemic that the problems of online STEM education are nothing more than issues of fairness, quality, and student participation. Amunga proposed three alternatives. The government should take an active role in addressing the issue of hardware equipment such as

electricity in rural areas and other rural areas. Priority should be given to the needs of disadvantaged groups for online teaching based on social fairness and justice. Finally, some academics proposed the use of augmented reality and virtual reality. Technology aids in the implementation of online courses, but the demand for technology and hardware is even greater. It will take time to achieve universal application. It is proposed that some physical laboratories be set up for students to use in order to solve the current problem. It appears that it can be implemented immediately, but it will require the sharing of laboratory equipment, subsequent disinfection, and more teaching time for teachers. These invisibly multiplied workloads leave us as STEM teachers perplexed. Furthermore, due to funding and equipment constraints, STEM courses are frequently delivered in conjunction with research projects. In the educational research project section, Verma et al. (2020) discovered that the STEM course plan could no longer be carried out due to the epidemic. This may be related to the relatively high and stable demand for STEM courses in terms of funding and course time continuity.

However, online education is not without flaws. Knowledge-based courses, such as lecture-based courses, are ideal for online instruction (Agarwal & Kaushik, 2020). Liguori and Winkleu both agree that basic knowledge is well suited to traditional teaching. Teaching creativity may necessitate the development of new online teaching methods. The enormous challenge of "how to teach" puts teachers' agility and innovation to the test (Liguori & Winkle, 2020). Teachers' comprehension of concepts that students lose when taking online courses, practical course implementation, course continuity, teaching creativity... These are all issues that teachers may face if STEM courses are moved online.

STEM teachers' characteristics are changing as a result of changes in online education

Denton and Borrego (2021) reviewed the literature from 2011 to 2020 and found only 15 papers on STEM teaching research over the previous ten years. However, after 4.5 months of Google Scholar searches for "STEM" and "teacher" keywords, we discovered 165 papers between January and April 2021 (after which time the world began to suspend classes one after the other) (Figure 1). This was more than ten times the number in the previous ten years. This demonstrated clearly that the STEM fields would flourish in the near future. Amongst the documents found, 33 papers specifically mentioned the characteristics that STEM teachers should have. These traits were classified into three categories: computational thinking (CT), pedagogical content knowledge (PCK), and self-efficacy (SE). Yadav's team (2014) believed that CT includes CT1 (Relationship to other disciplines), CT2 (Integrating computational thinking into the classroom), CT3 (a View of computational thinking). PCK was defined by Magnusson et al. (1999) as Knowledge of Science Curricula (KSC), Knowledge of Students' Understanding of Science (KSUS), Knowledge of the Assessment of Scientific Literacy (KASL), and Knowledge of Instructional Strategies (KIS). This questionnaire was commonly used to assess the PCK of science

teachers. According to Kao et al. (2011), there are six types of self-efficacy: personal interest, occupational promotion, external expectations, practical enhancement, social contact, and social stimulation. The study had questionnaires directly related to the development and evaluation of teachers. Typically, these questionnaires were used to investigate science teachers. Caton believes that in 2021 it was critical to better understand the challenges and obstacles faced by STEM field teachers to support those who were developing and implementing integrated STEM instruction (Caton, 2021). We can come to know about the characteristics that scholars believe STEM teachers should have before teaching online due to the epidemic from this search.

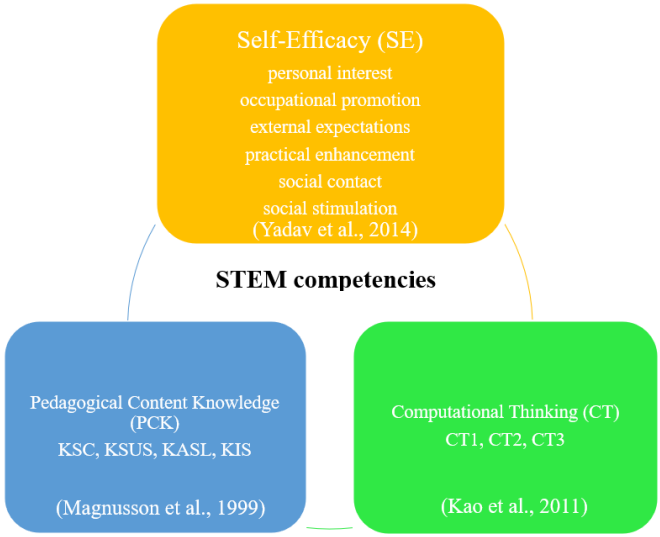

Figure 1. STEM teachers, according to academics, require competencies.

In this age of information overload, teachers need to discuss and use technology in addition to PCK. They need to expand the skills and knowledge required of them with a "holistic view." Mishra and Koehler (2006) proposed a need for technological pedagogical content knowledge (TPCK). In addition to adding technological elements, TPCK emphasized connection with the situation. When viewed individually, PCK can be considered a single component. According to TPCK, the overall sense was adjusted to the context and Thompson and Mishra renamed it TPACK in 2007. This emphasized it as a dynamic whole as well as the conceptual framework of teacher knowledge (Abbitt, 2011). According to transfer theory TPACK is made up of various aspects of knowledge that are interconnected. Personal experience will drive each knowledge component to form a complete individual (Abbitt, 2011; Angeli & Valanides, 2008; Niess et al, 2009). The more frequently the teacher used this method of learning, the easier it was to advance to the next level and integrate the cognitive architecture into TPACK.

According to Iswadi et al. (2020), the methods used to improve teachers' TPACK and STEM competencies are mixed and are influenced by materials, student characteristics, types of

integrated technologies, and so on. STEM learning is learner-based and influenced by student characteristics. As a result, the teacher can correctly identify the students' characteristics. It could also be one of the required skills. Asempapa et al. (2021) provided assistance to college students in STEM fields in four areas: faculty mentor, peer mentor, industry mentor, and learning center research activities internships, and discovered that such multi-faceted care can indeed promote success. The development of students in the field of STEM demonstrates that the abilities and characteristics required of STEM teachers are very diverse. DeCoito and Estaiteyeh (2022) believe that in online courses, STEM teachers' performance in TPACK and self-efficacy is important because it influences the success or failure of online teaching. According to the literature reviewed, STEM teachers face numerous challenges in terms of the explicit and implicit knowledge and abilities required, and even TPACK has unique characteristics that are closely related to personal experience and cannot be attained overnight.

Methods

A qualitative design approach was used in this case study (Creswell & Guetterman, 2019). With classes suspended due to the epidemic, a total of 9 STEM teachers were interviewed, with each teacher being interviewed three times. The case study approach is appropriate for understanding how people interpret, construct, or create meaning from their world and experiences, frequently in a highly inductive manner (Crowe et al., 2011, Kahlke, 2014), and it was well suited for use in this study as a tool for understanding STEM teachers' experiences. In comparison to the collected literature, we hope to use this opportunity to better understand how teachers' characteristics will change in the face of a sudden shock (large-scale class suspension), and how teachers will adjust. The inductive method is used to analyze the articles in this study. After summarizing the findings Its differences from the theoretical framework of the literature.
The first interview occurred within the first week of classes were suspended throughout Taiwan. The interview lasted about 25-35 minutes per person. The goal of this study was to get a clearer idea of the challenges that STEM teachers faced as they transitioned from FTF to the online teaching precipitated by the COVID-19 epidemic, how well they were able to respond, and what changes were implemented.

Participants

The author asked interviewees in Taiwan's science teachers and maker communities an online question. The perspectives of nine teachers who agreed to be interviewed for this project are presented in the results section. The nine educators are all current official national and high school teachers who have previously taught STEM courses in Taiwan (Table 1).

Table 1.
Participants' teaching subjects

Subject	**S**	**T**	**E**	**M**	Natural Sciences: Inquiry and Practice
Participants	SP1, SP2, SP3, SP4, SC1, SE1, SB1	T1, M1, SP4	SP1, SB1	M1	SP2, SP3, SP4, SC1, SE1, T1

If the participant had a university degree and had taught the subject, we used the participant code as the primary teaching subject. There were four Physics (SP1-4) teachers, one Chemistry (SC1) teacher, one Biology (SB1) teacher, one teacher of Earth Science (SE1), one Information Technology Education teacher (T1), and one Mathematics teacher (M1). Two of the teachers received second-specialty credit class certification during the teaching process, so SP1 and SB1 also taught Technology, and M1 was enrolled in an AI course which included collaborative lessons with other teachers at the same school.

Another thing to note is that the Curriculum Guidelines of 12-Year Basic Education have been implemented in Taiwan since 2019, and include interdisciplinary inquiry and practical courses. SP2 and SP3, SP4, SC1, SE1, and T1 all taught inquiry and practical courses or the same type of interdisciplinary courses during this study.

Data aggregator

The primary data collector was a chemistry teacher in a senior high school with 18 years of teaching experience that included interdisciplinary courses. He had led more than 30 scientific projects and was experienced in the creation of STEM course plans. He used Google Classroom to collect homework and conduct differential instruction, and so on. He was also willing to learn new technology and software in his spare time to help with teaching and also allowed students enough leeway for the inclusion of a range of learning styles and presentations. During the project he engaged in online teaching and also the return to FTF courses.

Procedure

A qualitative research method based on Sintema's interview questions (2020) was used in this study. The first interview was conducted over the phone, while the second was conducted using a Google form with follow-up questions based on the telephone response. The third interview was FTF or conducted by phone, see Figure 2. However, before each interview, participants were interviewed outline. Recordings were made with the participant's prior consent. The interviews were semi-structured and participants were asked to discuss their preparations for teaching at the time and previously (before the pandemic) and also to discuss

their feeling about the matter. The interviews went deeper (based upon response) to explore the participants' insights and concerns.

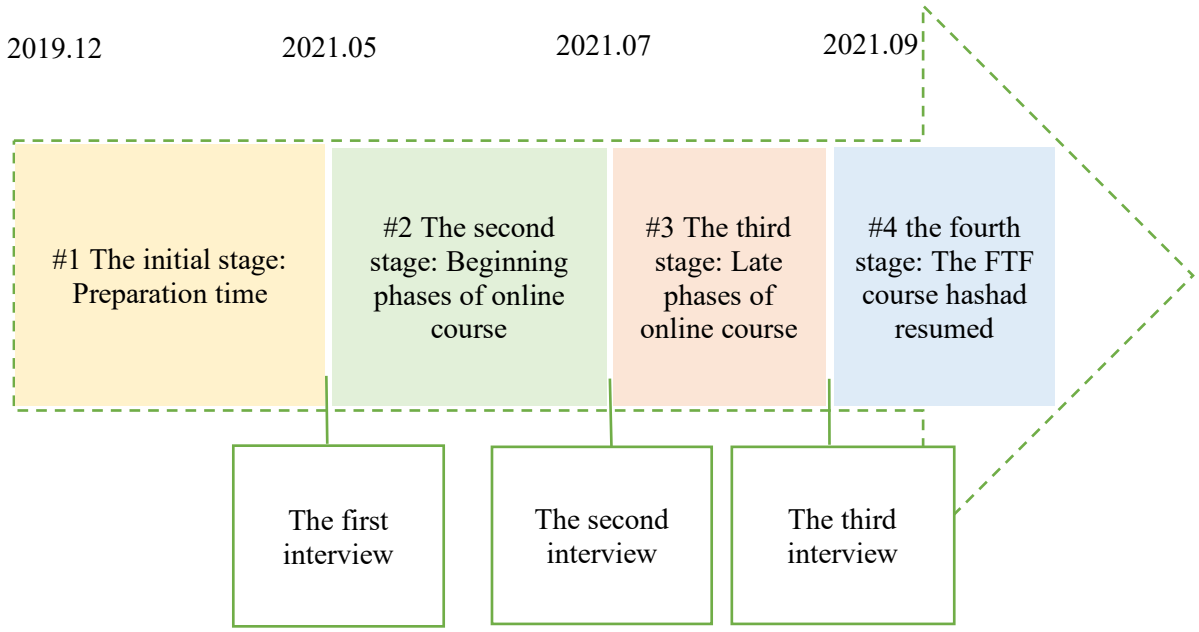

Figure 2. Schedule for data collection

Data Analysis

Data were transcribed and analyzed using the appropriate qualitative data analysis techniques. To avoid bias, data transcription and coding were performed by the researcher and one other independent person. Any discrepancy or inconsistency was discussed and resolved.

Induction was used by researchers to conduct qualitative analysis of the data collected (Peräkylä, 2005). An iterative analysis process was carried out by the author and another researcher. The data was examined independently by each after the first iteration before a meeting was held to generate classification that characterized the range of patterns observed in the data set. The data were then given another round of independent analysis, during which re-examination was done based on emerging themes to develop consensus codes based on the literature and data. Finally, the data and inter-code reliability were reviewed independently by the researchers and found to be greater than 0.85 for each data source, as measured by the Cohen α coefficient.

Results

#1 The initial stage: Preparation time

The nine teachers had never used online teaching before, but they were all familiar with online video and audio and also used it in the classroom. Because some countries have closed

their schools, the school required all teachers to create an educational version of Google accounts (100%), practice using Google Classroom to send homework assignments (100%), students also had enough practice submitting homework online (89%). Each school also looks into whether students had enough equipment (computers or tablets) as well as satisfactory access to the Internet.

Teachers needed to learn to use several different programs on different software platforms as part of their preparation. Regular FTF meetings have been converted into online video conferences allowing them to be continued and also allowing teachers to become acquainted with the use of online communication platforms. The majority of the online teaching platform options have been chosen by the schools and during the preparation period, most of the teachers involved set up student LINE groups to facilitate communications.

The real time for teachers to prepare their online classes is from the afternoon of the day after the announcement of suspension to the following day. After the announcement of the suspension of classes, each school assigned special times for the instructor to carry out the last one or two classes and entrusted them to remind students about the need to study online and help them to do it, sometimes the whole school practiced online operations at the same time. Students who had equipment or network issues could also pick up an iPad and a network interface card at school and take them home. Those who did not feel pressure before starting the online course were the information teachers, because the others had not really done any online teaching all day. When it came to preparing for online courses, the majority of the sources that helped teachers overcome online teaching difficulties were peers and school administrators.

After the information from the teacher interviews had been complied, the insights and concerns the teachers had about in the interview materials, were summarized. Attempts were made to assemble the insights into characteristics the STEM teachers had discussed in the literature and a new construct was created, see Table 2.

Table 2.
What are teachers most concerned about during preparation?

Interview data	**Insight**	**Construct**
... I was afraid that the students would miss the lesson and not come online... (SE1-1-P-w1)	Concerned about students not using the internet.	Learning Motivation/ Classroom management
Our school is in an aboriginal community... I am concerned that their equipment will not be adequate to support online learning. (SP3-1-P-w1)	Concerned about internet speed and equipment available to students.	Devices and Equipment for Students

Interview data	Insight	Construct
I'm concerned that students will not be able to concentrate.... Or perhaps they are off doing their own thing. (SP1-1-P-w1)	I'm concerned about whether or not the students are paying attention.	Learning Motivation
Blackboards are used to teach mathematics in FTF classes, Online tools such as the Jamboard may not be adequate and operation may not be so easy. (M1-1-P-w1)	Concerned about the teacher's equipment and knowledge	Devices and Equipment for Teachers

#2 The second stage: Beginning phases of online education

In terms of online teaching, all case teachers used Google Meet, and the vast majority (89 %) used Google Classroom or Google Drive to send homework or materials. The majority of them were graded on Google Classroom homework and in-class answers. Teachers' concerns during this time period were roughly classified as described below and followed by the Interview data and our summarized construct:

1. Concerned that students will not interact with the teacher, and dampen the teacher's enthusiasm for the class. (n=4, 44%). The following is an excerpt from the interview data:

   Students cannot keep the camera on for extended periods because it consumes a lot of power... There appears to be no response... We can't tell what others are thinking... If this is the case, I'm afraid I'll become depressed. (SP3-1-B-w1)

This is a component of Knowledge of Students' Understanding of STEM (KSUS) and Knowledge of Instructional Strategies (KIS)

2. Group discussions are not permitted for inquiry and implementation. (n=4, 44%)

   In a FTF class, you can appreciate what is going on and hear what the entire class is discussing. It is clear that a discussion is going on in a group... but online, everything is goal-oriented... when is a group discussion going on? We have no idea. (SP2-1-B-w1)

This should be classified as Knowledge of Instructional Strategies (KIS). There are others in addition to these: "difficult student grouping" (n=4, 44%)", the issue with writing on the blackboard" (n=4, Approximately 44%), "roll call is time-consuming" (n=5, Approximately 55%), "I was unable to sense the students' learning from facial expressions and body language" (n=3, 33%), "there are no materials, equipment, or tools to be purchased, and a few programs must be paid for" (n=4, 44%), "there is no way to stick to the original teaching schedule (the mode needs to the changed)" (n=3, 33%), "The effect of students using various classroom equipment" (n=2, 22%).

In addition to being concerned about online teaching, all the case teachers recognized the benefits of online teaching, but only 67% of them could clearly articulate those benefits. Including

the high rate of attendance, some classes have higher attendance than the original FTF classes, and students become more attentive in class, there is more mutual assistance, instant delivery of videos, notes, and assessments, improved classroom atmosphere, and a more comfortable teaching environment for teachers.

#3 The third stage: Late phases of online education

Case teachers reached a stage in online teaching where final exams had to be changed for online processing. The teachers faced more challenges and their concerns evolved and were of the following nature:

1. Concern about unjust assessment. (n=7, 77%). The following is an outtake from interview data:

There is no way to hold a traditional exam, and I am concerned that the validity of online exams will be limited (SP4-2-L-W1)

This should fall under the categories of Knowledge of Instructional Strategies (KIS) and Learning Effectiveness.

2. There is no FTF communication with students. (n=4, 44%)

Students who refuse to study in class cannot be interviewed in person (SP2-2-L-W1)

This should be in the category of classroom management.

There are others in addition to these: "Because the implementation cannot be evaluated, you should focus more on task-based work" (n=7, 77%)", strategy for online education" (n=7, 77%), "integration of resources, teaching fluency, and a shift in class rhythm" (n=7, 77%), "Interaction with students" (n=5, 55%).

#4 the fourth stage: The FTF course has resumed

Table 3.
The evolution of teachers' concerns prior to and following online instruction

	#1 The initial stage	**#2 The second stage**	**#3 The third stage**	**#4 the fourth stage**
Technology Equipment for Students	3	7	5	6
Technology Equipment for Teachers	2	3	1	0

	#1 The initial stage	#2 The second stage	#3 The third stage	#4 the fourth stage
Classroom management	1	5	5	1
Learning Motivation	7	1	8	3
Learning Effectiveness	0	2	7	4
Knowledge of Assessment of STEM Literacy (KASL)	0	0	4	0
Knowledge of Students' Understanding of STEM (KSUS)	0	4	1	3
Knowledge of Instructional Strategies (KIS)	0	4	7	3
Knowledge of STEM Curricula (KSC)	0	5	5	1
Integration and application of technology and disciplines	0	4	2	0
Personal Interest (SE1)	0	3	1	0
Workload expansion	0	2	4	0

Note: The higher the curve, the more concern has been expressed by the teachers. A concern is only recorded once even if it has been expressed multiple times in a period and each item involves a maximum of 9 case teachers for each period.

Table 3 was used to organize the evolution of teachers' concerns prior to and after online instruction. Everyone is concerned about how to implement online courses during the initial stage and the second stage. They are concerned about the information technology used by students and teachers. Teachers focus on the equipment required for students in the early and late stages of online teaching. Purchase or replacement of appliances, software, and machines. The teachers were still concerned about the equipment after the FTF course resumed. They were concerned about having to deal with new students if the class was suspended again. The equipment new students had was not necessarily reliable and they sometimes had no idea how to reach them. Furthermore, teachers were well aware that when exploratory experiments were being conducted using students' equipment the environment under which the students were doing the work was not the same as that of the laboratory. How could such experimental results be compared? This was a serious issue of concern for the teachers. DeCoito and Estaiteyeh (2022) also talked about the importance of face-to-face interaction in their online course for STEM teachers. They believe that this problem can be solved through social media, but through our more detailed survey, we found that the inability to face-to-face affects the STEM field. There are more details of the impact, I am afraid that it cannot be solved by simple social software.

After online teaching, teachers frequently mention "FTF Interaction." "People" to "people" including teachers to students, the entire class to a student, a group to a group, and so on. The lack of face-to-face interaction with students had caused the teacher's enthusiasm and motivation to dwindle. Case teachers know that student's smiles increase their motivation to teach. If they have met before and there is a friendly or warm connection between the teacher and the student a smile is an easy thing to promote. Teaching students you have never met online is a huge challenge in the face of an unstable epidemic. The absence of FTF interaction also has a significant impact on the teacher's interpretation of the state of a student's gain of knowledge.

> *…. I noticed a student with a puzzled expression after I finished teaching a concept. He didn't ask a question, but turned and whispered to the student beside him, …Then I guessed that the concept he had just now heard presented a problem, so I simply repeated what I had said and the student showed an expression of sudden realization. I could not have seen this during an online class… (SC1-3-F-W2)*

In addition to the emotional benefits of being able to speak directly with students FTF contact allows teachers to see if homework has been completed at a glance. More importantly, the teacher believes that being in front of the students encourages them to learn more rigorously.

In all the cases mentioned by teachers a common concern was that teachers were "not sure if they're paying attention." Determination of the degree of attention a class is paying is difficult and teachers can no longer be certain about this, making a determination about whether methods are effective or not was a very difficult task. These methods include the calling out of names, and other class management methods, such as real-time tests, and changes in teaching strategy. The lack of "FTF interaction" has a real impact on the quality of the class discussions and questions. Online, you can only see the finished products of other groups, not the process by which they have been achieved. Teachers believe that online teaching in the context of inquiry and practice can only achieve near-passable results.

Teachers put a lot of effort into "realizing" synchronized online courses in the early stages of online teaching and pay attention to learning motivation in the later stages of after they think the students have become accustomed to the rhythm. Online education is not a new idea and teachers and are experimenting with new strategies because they are concerned about effectiveness of the present ones. When teachers returned to FTF teaching their main concern was the effectiveness of the lessons the students had received online. The teachers also believed that the students were looking forward to school and to seeing the teacher and their friends. However, many students appeared agitated and old normal behavior was not resumed. Teachers will need more task-oriented activities in the curriculum if they are to maintain concentration for an extended period of time. All the case teachers agreed that online teaching widened the degree gap between students. Active students and those with self-learning ability were improving, but those who do not discuss or participate were deeper into retreat.

Discussion and Implications

Our lives, as well as our teaching, have been altered as a result of the epidemic. In response to the epidemic, the Taiwan Network Information Association (2022) conducted a survey from February 14th to March 15th, 2022, and discovered that 21.6% of the public still used remote work or distance teaching during that time period. At the same time, as many as 67.48% of remote workers and 74.10% of distance teaching teachers expressed a desire to stop working or teaching remotely after the epidemic.

The findings of this project have shown that many of the anticipated difficulties were not as had been expected. Of course, there were numerous benefits that could only have been appreciated after they had been experienced. Researchers will discuss teachers' PCK (or TPACK), SE, and CT characteristics, just as they had done before the epidemic (Denton & Borrego, 2021). However, the aspects of online teaching that most concerned the teachers were "equipment," "student motivation," "class management," and "increased workload". We discovered that, similar to online learning in MOOCs, STEM teachers of online courses must be very familiar with the

misconception of students (Chen et al, 2020). Preparation for various types of interactive use, such as experiments and question periods, are frequently required in STEM courses (Crawford, 2012). According to Evagorou and Nisiforou (2020), preparing for online or blending teaching will be a significant and growing challenge for STEM teachers. In our findings, the difficulty of online classes or blending teaching in STEM courses is greater than that of general practical courses because "each student's experimental environment is different and it is difficult to control the variables." More thought must be given to curriculum design in order to solve this problem.

STEM employers believe that STEM talent requires the following soft skills: teamwork, collaboration, leadership, problem solving, critical thinking, work ethic, perseverance, emotional intelligence, organizational skills, creativity, interpersonal communication, and conflict resolution. Otherwise, as technology advances, people who lack these soft skills will be surpassed by machines (Karimi & Pina, 2021). Employers' requirements are quite high and diverse, as can be seen from these needs. In the STEM field, in addition to knowledge and skills, many soft skills must be developed in the curriculum. With such high demand in the back-end industry, do we, as front-end educators, have enough capacity to meet it? According to Aykan and Yildirim 's (2021) research, teachers have some negative attitudes toward distance learning. These considerations should be taken into account by researchers when designing future studies. They should also concentrate on blended learning, where teachers struggle to incorporate STEM fields into their lesson plans due to knowledge gaps. Original PCK (or TPACK) emphasis had been on how to "realize the desired course requirements online." In this study, the case teacher did not discuss the CT, which has been discussed and valued throughout. In comparison to the previous study (Aykan & Yildirim, 2021), our study discovered unexpected difficulties as a result of a lack of "FTF discussions" among STEM teachers during the research process. And this difficulty may have an impact on the development of soft skills. In comparison to DeCoito and Estaiteyeh (2022), we all investigated the coping strategies and feelings of STEM teachers when classes were suspended for the first time due to the epidemic. Despite the fact that our research methods differed, we both used TPACK and SE as theoretical frameworks for testing. Our research has clearly seen the changes of teachers in various stages of coping after three interviews, and we have also made deeper discoveries about the plight of many teachers.

After returning to FTF interaction with their students most teachers were of the opinion that certain parts of online teaching were advantageous and should be retained to supplement FTF course teaching. The case teachers were also of the opinion that their flexibility had increased, and they could now accept more diverse homework and teaching styles than previously. Even teachers with many years of experience accepted these changes and hoped to make use of the many newly discovered online benefits to supplement their teaching.

The best friend and worst enemy of a STEM teacher is “resilience”. Teachers had plenty of leeway in STEM teaching in terms of teaching materials, tools, and methods, but STEM

restricted to the Internet necessitates more consideration and support in the selection of the type of activity and materials.

Conclusion

This study demonstrates the difficulties and concerns experienced by teachers as a result of the pressure generated by the rush to popularize online teaching in such a short time. However, two days after classes had been suspended, almost all schools in the country began to formally synchronize online teaching, and student attendance was surprisingly high. In fact, participation was almost the same as for normal FTF teaching and this was something that had not been anticipated.

STEM teaching is limited by the availability of the devices and services needed for its implementation. Students and teachers are also faced with other significant challenges and difficulties which need to be discussed. For example, curriculum changes or rearrangement seriously tests the familiarity and adaptability of the teachers involved and this aspect needs attention. The study also discovered that the challenges that STEM teachers face are quite complex and diverse, and that STEM teachers' online teaching experiences can indeed become an important reference for teachers of other disciplines.

In this study all the changes in method and characteristics elicited by online teaching of STEM were compared with those in use before the advent of large-scale online teaching. STEM educators were able to use these differences to make changes to the methods and make the adaptations necessary for STEM teaching in the new world of online teaching. Taiwan has now returned to FTF teaching and everything appears to have returned to the familiar teaching mode. We seem to be more like the original us, but there are now some differences. When research data is discussed and analyzed these days it is done by people who are interacting personally. However, they often use Google Meet to share information for discussion across the table between them. This is now the way that information can be shared and records made. These new habits, that are in wide use now, should have been in use years ago.

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