Synchronous Display and Whiteboard-Like Freehand Writing App as Teaching Tool for Virtual Classroom amidst the Pandemic [version 2; peer review: 2 approved, 1 approved with reservations]

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Abstract

Purpose: The research evaluates if teachers can achieve better teaching outcomes by using a proposed mobile interactive system (MIS) developed for this study as an additional approach to enhancing teachers' proficiency in Technological Pedagogical and Content Knowledge (TPACK) in the virtual classroom.

Background: According to previous studies, teachers' self-assessment on TPACK might be affected by their ego because they have autonomy over the students in the classroom. Some studies suggest that utilisation of an interactive whiteboard (IWB) promotes creativity in teaching and learning but that it is unsuitable for a virtual environment due to its large size and the high maintenance costs associated with owning one in a teacher's residence. Besides, some studies also reveal that allowing the students to assess their teachers through TPACK is able to reduce potential errors which might result from the TPACK self-assessment done by teachers.

Methods: Pre- and post-experiments were conducted with the developed MIS integrated into teaching process. Synchronous display (SD) and whiteboard-like freehand writing (WFW) were features of the MIS integrated into the experimental group. Questionnaires were distributed to the students, and a reflective measurement model was formed using SmartPLS and IBM SPSS Statistics.

Findings: Based on our findings, teachers' Technological Content Knowledge had a significant positive effect on TPACK with the inclusion of MIS in online teaching. Predictive relevance was also evaluated through a $Q^2$ value to predict the endogenous construct of the constructed model. The $Q^2$ value was greater than zero, indicating that the model possesses a predictive relevance.

Conclusion: The integration of the developed MIS in the virtual classroom has a significant positive impact on the students' academic
performance relating to concept learning and knowledge acquisition of subject matter.

**Keywords**
Mobile Interactive System, Virtual Classroom, TPACK, Educational Technology, COVID-19, Synchronous Display, Freehand Writing, Teaching Tool

This article is included in the Research Synergy Foundation gateway.

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**Author roles:** Lai D: Conceptualization, Data Curation, Formal Analysis, Software, Validation, Visualization, Writing – Original Draft Preparation; Sook Ling L: Conceptualization, Data Curation, Funding Acquisition, Methodology, Project Administration, Resources, Supervision, Writing – Review & Editing; Yin OS: Conceptualization, Supervision, Writing – Review & Editing

**Competing interests:** No competing interests were disclosed.

**Grant information:** This research is funded and supported by Multimedia University and Fundamental Research Grant Scheme (FRGS), Malaysia with Grant Reference Number: FRGS/1/2018/SSI09/MMU/02/3. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

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**How to cite this article:** Lai D, Sook Ling L and Yin OS. Synchronous Display and Whiteboard-Like Freehand Writing App as Teaching Tool for Virtual Classroom amidst the Pandemic [version 2; peer review: 2 approved, 1 approved with reservations] F1000Research 2022, 10:1308 https://doi.org/10.12688/f1000research.73531.2

**First published:** 22 Dec 2021, 10:1308 https://doi.org/10.12688/f1000research.73531.1
Introduction
Background
The outbreak of COVID-19 in 2020 caused a significant impact on the education sector. Pedagogy has changed drastically to cope with the pandemic and has many cases shifted from conventional in-classroom learning to online teaching. The classical in-classroom teaching and learning is commonly practised to promote social interactions among teachers and students. However, it is now unable to fit well into the current education environment due to the pandemic. Because of this, the rapid evolution of technology will alter pedagogy where emerging technologies are accessible in education.

Additionally, teachers solely depend on the mouse and keyboard to conceptualise subject matter where conventional tools are prohibited in the virtual classroom. Hence, emerging technologies are excellent for content presentations in the virtual classroom. From students’ perspective, attending lessons via synchronous learning video conferencing is preferred as it offers flexibility. Students are engaged in the virtual session as much as in the physical classroom. However, the effectiveness of integrating technology in conducting online classes is questionable. In the Vasodavan et al. study (2020), the teachers are incompetent in incorporating technology effectively into their lessons and activity. They do possess solid knowledge of the technology, but they can hardly fit this technology, especially into their teaching practices when it comes to integration. Hence, collaborative teaching is less effective when the teachers cannot identify the most appropriate technology to support their teaching practices.

Furthermore, technology integration in education never proposed an ultimate solution but offered an alternative. Therefore, technology should not be the sole reason for being blamed as an instrumental issue. Besides, technology integration in the classroom leads to more issues or is somewhat problematic. Therefore, technology integration in education should emphasise alternativity instead of betterment in which the claim of “better technology” is very vague. The choice of technology should not consider only the latest trend but consider its functionality and suitability. There is no technology that can fit into all scenarios and criteria.

Moreover, the teachers are unprepared for the sudden transition to the online teaching approach. Due to the lack of experience in online classes, they are not proficient in using unfamiliar technology to conduct classroom activities that they used to in the conventional class. For example, one of the mandatory technical skills required for the online class is video conferencing with the synchronous presentation in the virtual classroom. In addition, insufficient technical support from academic institutions leads to teachers’ incompetency in teaching with technology. It somehow hinders the students’ understanding of the subject matters.

Additionally, the teachers with less experience and lower efficacy with information and communication technology (ICT) tend to undergo more negativity while teaching online classes. Their willingness of adopting technology in their teaching was mainly due to their prior experience and perceived value towards the technology integration.

The adoption of the TPACK model aims to help teachers contemplate their knowledge domains (technological, pedagogical, and content knowledge) and the intersections of these to teach and engage students effectively. According to Hossain, Ying and Saha, TPACK positively influences higher education by making the lessons more interesting by observing learners’ needs. From their studies, students have positive attitudes towards the TPACK model, in which their feedback can be addressed and used to construct lessons tailored to their needs. Moreover, teachers’ TPACK self-efficacy is enhanced in lesson planning with technology.

Problem statement
Since the students are prohibited from entering their physical classes, teachers face challenges and difficulties when conducting online classes via the virtual classroom. The practice of conducting classes through the virtual classroom...
sacrifices the benefits experienced in the conventional classroom environment.° It negatively affects the students’ knowledge acquisition of the subject matters from their teachers. Additionally, teachers are requested to prepare teaching materials and determine ways to present them in the virtual classroom. Although teachers nowadays are primarily aware of and understand the nature of technology and its functionality, they commonly face challenges in integrating the technology effectively into their pedagogy. ³ Thus, research questions are drawn as follows:

- Research Question 1: Does the integration of MIS into the virtual classroom enhance teachers’ self-efficacy from students’ perspectives in TPACK?
- Research Question 2: Does the integration of MIS into the virtual classroom enhance teachers’ efficacy in presenting and conceptualising teaching materials?

Objectives
Since the introduction of the virtual classroom, it has become evident that it is essential to have a simple-to-use, tailored tool for assisting teachers in conducting online classes according to the current educational trend. Consequently, a mobile interactive system is proposed and developed to cope with the current trend. Furthermore, the introduction of the MIS offers teachers the ability to utilise the features of synchronous display (SD) and whiteboard-like freehand writing (WFW) features. Thus, the objectives are as follows:

1. Determine if the introduction of MIS features enhances teachers’ proficiency in TPACK from students’ perspectives.
2. Determine teachers’ efficacy in presenting and conceptualising teaching materials by constructing a model based on the integration of MIS with the adoption of the TPACK framework in the virtual classroom.

Literature review
Virtual classroom
In following the standard of procedures set by the government to reduce close contact, the transformation of the current education system is necessary. Thus, conducting classes through online platforms has become a new trend in education. In the virtual classroom, classes are taught online synchronously via video conference. However, acquiring new skills and knowledge relating to communication, pedagogy, content, and structure is required due to distinctive differences in the teaching environment. However, with the introductory of online courses, the curriculum planning gained more flexibility and openness. Sometimes, students were assumed to adapt to technology instantaneously without any guidance and training because they were digital natives.

Nevertheless, that statement was debunked in Andrew’s study. He mentioned that the teachers and students were equally needed guidance on conducting effective communication and interaction in the online classes. From his findings, the teachers had a positive attitude regarding their interaction in the online class while the students had it otherwise. It was due to the different points of view of the teachers and students perceiving the interaction, social quality and teaching presence in the online class and blended learning. One of the teachers’ common external factors in curriculum design and planning was the lack of control. The syllabus of the subject matter could be pre-design according to particular learning outcomes. Hence, the teachers were not given complete authority in selecting more appropriate teaching approaches and content selections for teaching. The hybrid teaching approaches within one course could hinder the full potential of online learning as it sacrificed the flexibility in course design. The interaction between the teachers and students in the online class was a significant limitation due to the poorly designed online course.

Interactive whiteboards
The combination of IWB with a virtual learning environment (VLE) exists with limited studies. According to Heemskerk, Kuijpert, and Meijer’s study, implementing IWB with VLE can boost students’ motivation towards the subject matter. However, the test given by teachers proves that it is ineffective to students’ learning outcomes even with the implementation of IWB and VLE. Furthermore, the IWB is an expensive and fragile device as it can be damaged easily, resulting in inconvenience when teaching with it, which does not justify long-term usage. Besides, teachers still retain complete autonomy in the classroom, creating a teacher-centred environment while teaching with IWB.

As a result, the students who learned in an IWB-based instruction classroom had more interest and motivation in learning. Furthermore, integrating IWB in the classroom allowed the teachers to alter the teaching practices with more classroom activities that support their teaching academically. However, implementing interactive whiteboards in the classrooms did not improve students’ learning achievement. In short, IWB is not practical to be integrated into the virtual
classroom because the IWB is difficult to maintain and not friendly for teachers who conduct classes at their residence during the pandemic.

TPACK framework
As a teacher, one must be aware of and adapt to any changes, honing skills and knowledge to guide and expose students to state-of-art technologies in the virtual classroom.22 However, insufficient teaching experience via virtual classrooms forces teachers to polish their skills and knowledge. Hence, they can cope with the current education phenomenon. As a result, the pedagogy and teaching materials presentation are elevated.23 Therefore, the TPACK framework is adopted. It consists of seven elements, the three main elements being technological knowledge (TK), pedagogical knowledge (PK), content knowledge (CK), which are derived into four sub-elements pedagogical content knowledge (PCK), technological pedagogical knowledge (TPK), technological content knowledge (TCK), and TPACK.24 Initially, the TPACK framework is teachers’ self-assessment about the thoroughness of their understanding of every element, including the teachers’ “know-how” in utilising the technology and integrating it into their pedagogy and teaching materials presentation.25 However, assessing it from the teacher’s or student’s perspective brings different meanings. For example, the teachers’ perspective is viewed from the educator’s perspective, whereas the students’ perspective is viewed from the virtual classroom experience created by their teachers.26 In short, the TPACK framework is vital because it helps assess the readiness of teachers’ knowledge and understanding in using technology integrated into their pedagogy and content presentation, both from the teachers’ and students’ perspectives.

Methods
Overview
Rickles et al. (2017) mapped their research elements (Learning Environment Context and Learning Activity Context) with the adoption of the TPACK framework.27 The Learning Activity influenced TK, PK, and CK, while the Learning Environment Context may affect all elements, including Learning Activity Context. Hence, the study proposes that the Learning Environment Context supports the relevancy of Learning Activity Context as complimentary learning. These two contexts are the keys of context-based learning (CBL), where the social aspect of learning and learning activity with solid context understanding in acquisition and processing knowledge are concerned. Moreover, CBL allows teachers to prepare early for teaching materials, making it easier to implement than problem-based learning, which is relatively time-consuming. Hence, the rapid change of teaching approach necessitated during the pandemic makes CBL more suitable for current phenomena in terms of content-oriented presentation. The overall flow in determining teachers’ self-efficacy in presenting and conceptualising teaching materials using MIS is illustrated in Figure 1. The experiment is designed based on a quasi-experiment. It consists of pre-test and post-test of an experimental group. The pre-test and post-test of the knowledge checking test share similar intention of the test conducted by Mustafa and Meric on learning achievement.28 As for the pre-test and post-test of TPACK, assessments are conducted to observe whether the difference is significant regarding the teachers’ improvement in TPACK knowledge domains’ understanding.29

Besides, a pilot study was conducted to gather feedback and insights from the students and experts before conducting the actual survey. The findings of the pilot study survey indicated that the users were showing a positive attitude towards the integration of the proposed MIS as learning media.

Participants
Cluster sampling was implemented. Students who experienced online learning with the integration of the MIS features were chosen as the cluster because of its capability to reduce sample bias. This data collection method provides a better representation of populations.30 Online questionnaires were distributed to 45 Malaysian private university students enrolling in “Knowledge Management”. The chosen group was taught with MIS integrated into their online classes.

Procedure
The experiment was conducted from the start till the end of the semester (3 months). This study is a quasi-experimental one-group with the pre-and-post-tests. The MIS is tailored for online classes with two major features: SD and WFW. The questionnaires were created to adopt the TPACK framework and prepared in two sets specifically for pre-test and post-test through Google Form. Besides, conducting TPACK self-assessment from teachers’ perspectives may lead to biases. The assessment can be inaccurate as assessing themselves is not convincing enough to reflect if their understanding is up to par.31 Thus, to reduce the bias from the teacher’s self-assessment, the student’s perspective on TPACK should be considered instead.32 The collected data is trimmed and analysed using SmartPLS software v3.3.2.R is an open-source alternative (R Project for Statistical Computing, RRID:SCR_001905).

Results
In this study, the adoption of the TPACK framework is proposed. The teacher’s efficacy mapped in conjunction with the integration of MIS in the virtual classroom is illustrated in Figure 2.
Figure 1. Flow chart of the integration of MIS and TPACK in the virtual classroom.
Figure 2. Adoption of TPACK framework with MIS teacher’s efficacy mapped.

Figure 3. Proposed model with the adoption of TPACK framework.
Through PLS-SEM, the proposed model is constructed in Figure 3 based on adopting the TPACK framework. Moreover, the proposed model is constructed as a reflective Measurement Model.

Firstly, after running Partial Least Squared Algorithm, the constructs’ outer loadings indicators are observed in Table 1. The loadings for the construct indicators are > 0.7.

Secondly, the construct reliability and validity are examined, as shown in Table 2. The threshold value for the composite reliability (CR) is > 0.70, while the threshold value for the average variance extracted (AVE) is > 0.5. In this study, the CR and AVE are fulfilling the threshold requirements as the values of CR are > 0.9, and the values of AVE are > 0.75. The CR values indicate good reliability, and AVE values indicate good validity.

Thirdly, the discriminant validity of the model is inspected. The Heterotrait-Monotrait Ratio (HTMT) is preferred because of its stringent measures with sensitivity rates of 97%-99%. On the other hand, the Fornell-Larcker Criterion is insensitive with a rate of 20.82%. Furthermore, the HTMT values of this study are above 0.85 and less than 0.90.

### Table 1. Indicators of the constructs’ outer loadings.

|       | CK    | PK    | TCK   | TK    | TPACK  | TPK   |
|-------|-------|-------|-------|-------|--------|-------|
| CK2   | 0.929 |       |       |       |        |       |
| CK4   | 0.888 |       |       |       |        |       |
| CK5   | 0.966 |       |       |       |        |       |
| CK6   | 0.950 |       |       |       |        |       |
| PK1   | 0.866 |       |       |       |        |       |
| PK2   | 0.894 |       |       |       |        |       |
| PK5   | 0.837 |       |       |       |        |       |
| PK6   | 0.820 |       |       |       |        |       |
| TCK1  | 0.920 |       |       |       |        |       |
| TCK3  |       | 0.941 |       |       |        |       |
| TCK4  |       | 0.948 |       |       |        |       |
| TK1   |       |       | 0.964 |       |        |       |
| TK2   |       |       | 0.935 |       |        |       |
| TK3   |       |       | 0.964 |       |        |       |
| TPACK1|       |       |       | 0.941 |        |       |
| TPACK2|       |       |       | 0.955 |        |       |
| TPACK6|       |       |       | 0.984 |        |       |
| TPK4  |       |       |       |       | 0.961  |       |
| TPK5  |       |       |       |       | 0.951  |       |
| TPK6  |       |       |       |       | 0.983  |       |

### Table 2. Construct reliability and validity.

|      | Cronbach’s alpha | rho A | Composite reliability | Average variance extracted (AVE) |
|------|------------------|-------|-----------------------|---------------------------------|
| CK   | 0.950            | 0.952 | 0.964                 | 0.871                           |
| PK   | 0.927            | 0.947 | 0.947                 | 0.819                           |
| TCK  | 0.930            | 0.933 | 0.955                 | 0.877                           |
| TK   | 0.951            | 0.957 | 0.968                 | 0.911                           |
| TPACK| 0.957            | 0.962 | 0.972                 | 0.922                           |
| TPK  | 0.963            | 0.965 | 0.976                 | 0.932                           |
(Table 3). Therefore, it satisfied the HTMT threshold. Hence, the discriminant validity between relative constructs is established. Next, the significance and relevance of the structural model in this study are assessed, as shown in Table 4. First, a One-Tailed test Bias-corrected and accelerated bootstrap (BCA) with bias and skewness adjusted are conducted. As research hypotheses are directional, the bootstrapping is with 5000 subsamples. Then, the path coefficients are obtained and further examined. The path coefficients values are closer to +1, representing strong positive relationships between latent constructs. Additionally, the path coefficient values should be at the least 0.05 significant level.

Next, the $R^2$ and $R^2$ adjusted values are shown in Table 5 are considered substantial.33

The effect size is calculated using the formula below:

$$f^2 = \frac{R^2\text{included} - R^2\text{excluded}}{1 - R^2\text{included}}$$

The results in Table 6 indicate that the TPK (0.109) has a negligible effect in producing the $R^2$ for TPACK. However, the TCK (1.008) illustrates that it has a significant impact on producing the $R^2$ for TPACK.

| Table 3. Heterotrait-Monotrait Ratio (HTMT) for discriminant validity. |
|-----------------|----------------|----------------|----------------|----------------|----------------|
| CK              | PK             | TCK            | TK             | TPACK          | TPK            |
| CK              | 0.834          |                |                |                |                |
| PK              | 0.861          | 0.781          |                |                |                |
| TCK             | 0.790          | 0.850          | 0.795          |                |                |
| TPACK           | 0.846          | 0.813          | 0.900          | 0.756          |                |
| TPK             | 0.894          | 0.879          | 0.730          | 0.798          | 0.735          |

| Table 4. Path coefficients. |
|-----------------------------|
| Original sample mean | Standard deviation (STDEV) | P-values |
| CK -> TCK          | 0.526         | 0.206    | 0.005*** |
| PK -> TPK          | 0.391         | 0.229    | 0.044*** |
| TCK -> TPACK       | 0.693         | 0.143    | 0.000*** |
| TK -> TCK          | 0.374         | 0.182    | 0.020*** |
| TK -> TPK          | 0.478         | 0.224    | 0.017*** |
| TPK -> TPACK       | 0.228         | 0.181    | 0.104    |

***Significant at 0.05.

| Table 5. $R^2$ and $R^2$ adjusted for calculating effect size. |
|-----------------|-----------------|
| R square         | R square adjusted |
| TCK              | 0.697           | 0.683           |
| TPACK            | 0.752           | 0.741           |
| TPK              | 0.659           | 0.643           |

| Table 6. Effect size ($f^2$). |
|-------------------------------|
| TPACK                         |
| TCK                           | 1.008           |
| TPACK                         | 0.109           |
The results for the blindfolding are in the rightmost column, which is shown in Table 7. The predictive relevance $Q^2$ of TCK has a value of 0.598, TPK has a value of 0.579, and TPACK has a value of 0.675. These values indicate that the model has predictive relevance based on the three endogenous constructs in which the values of $Q^2$ are considerably above zero.

As shown in Table 8, a paired-samples T-test was performed to identify the students’ improvement on their understanding of the subject matter with the integration of developed MIS. The mean score difference of $3.289$ shows that students’ understanding of the subject matter is improved. The p-value of $0.00000003178$ denotes that integrating the developed MIS in the virtual classroom positively affects the students’ academic performance. The improvement over the pre- and post-knowledge checking tests are substantially significant.

**Discussion**

The involvement of technology in education acts as a catalyst in transforming the conventional classroom into the virtual classroom. The extensive involvement of technology in the current education trend prompted the adoption of the TPACK framework in this study. However, educational tools such as interactive whiteboards are not practical in the virtual classroom, although they offer teachers various useful features. Therefore, the developed MIS is integrated into online teaching as a complementary pedagogy that assists the teachers in presenting teaching materials. Furthermore, the proposed model is constructed based on adopted TPACK framework elements. The consideration of students’ perspective TPACK is mainly a result of the potential bias and misconceptions raised by the teachers’ self-assessment on TPACK proficiency in the previous study. Instead, this study addressed and mitigated those issues by gaining feedback and insights from the students’ perspectives. The students’ feedback gives a more in-depth insight allowing teachers to adjust their teaching practices and content presentation of subject matter. From the result of the path coefficient, we can see that a teacher with great understanding in transforming the content delivering it to the students using developed MIS possess the ability to enhance classroom activities which reflects their proficiency in TPACK. This phenomenon explains the importance of technology selection in which the technology can be utilised. With the proper tool, the teachers can enhance the teaching and learning experience and overcome the technology integration issues faced in the past study. A well-fitted technology for teaching practices improves students’ performance academically. From the result of the paired-samples T-test, the mean difference for the pre-score and post-score indicates that the students are improved academically from concept and knowledge acquisitions. The outcome also illustrates that the teachers’ proficiency in TPACK is closely related to the effectiveness of the integration of developed MIS in the virtual classroom.

Additionally, the developed MIS with SD and WFW is tailored to assist teachers in conducting online classes. Familiarised teaching experience is replicated especially teaching materials presentation. Students’ feedback plays a

| Table 7. Construct cross-validated redundancy (CVR) Using blindfolding procedure. |
|-----------------|-----------|-----------|-----------------|
|                 | SSO       | SSE       | $Q^2 (= 1 – SSE/SSO)$ |
| CK              | 188.000   | 188.000   |                   |
| PK              | 188.000   | 188.000   |                   |
| TCK             | 141.000   | 56.685    | 0.598             |
| TK              | 141.000   | 141.000   |                   |
| TPACK           | 141.000   | 47.767    | 0.675             |
| TPK             | 141.000   | 59.319    | 0.579             |

| Table 8. Paired-samples T test. |
|-------------------------------|-----------|-----------|-----------------|
| Paired difference             | Mean      | Std. deviation | Std. error mean | 95% confidence interval of the difference | t     | df     | Sig (2-tailed) |
|                              |           |              |                 | Lower     | Upper   |       |            |
| Pre Score – Post Score        | $-3.289$  | $2.912$      | $.472$          | $-4.247$  | $-2.322$| $-6.963$| 37          | $.00000003178$ |
vital role in determining the proficiency and self-efficacy of the teachers. Therefore, it is essential to address more insights into integrating technology into the virtual classroom than teachers’ self-assessment. In this study, teachers’ integration of MIS into the virtual classroom affects the TCK and TPACK. It indicates that the thoroughness of teachers’ understanding of the technology in presenting their teaching materials determines their students’ learning experience in the virtual classroom.

In short, the technology integration in this study had proven that the proficiency of a teacher’s knowledge about TPACK domains and sub-domains is essential. It affects the student’s learning outcomes and academic achievements. The proposed MIS in the online class positively impacts the teaching and learning experience. In the virtual classroom, the teachers have limited choices of tools to present their content of the subject matter. On top of that, their efficacy in using technology is also varied. Hence, the proposed MIS gives the teachers an alternative way of presenting the content of the subject matter in the virtual classroom. In the meantime, their teaching techniques and practices were restructured and improved with the integration of the proposed MIS.

**Conclusions**

This study demonstrates the proposed structural model with the adoption of the TPACK framework and the integration of the proposed MIS with SD and WFW, assisting teachers in improving the online class experience with alternative teaching materials. Furthermore, the proposed structural model as a reflective measurement is constructed by adopting the TPACK framework as the fundamental. Looking at the relative importance of the exogenous constructs in predicting the dependent construct (TCK), it is evident that CK is the most crucial predictor followed by TK. The factor of TCK has a strong effect on TPACK. As for R², the value for TCK, TPK, and TPACK is considered substantial. The effect size for the TCK is considerably large. The student’s understanding of the subject matter is improved significantly with the integration of developed MIS by their teacher in the virtual classroom. In contrast with previous studies, the integration of developed MIS is more in accord with the virtual classroom, significantly enhancing teaching materials. The integration of the developed MIS in the virtual classroom has a significant positive impact on the students’ academic performance relating to concept and knowledge acquisition of subject matter.

**Limitation**

There were several limitations faced in this study. One of the most significant limitations is the number of respondents for the survey distributed. In addition, the students who participated in the experiment were pre-assigned and divided into smaller tutorial groups. Hence, the sample size is considerably small. Consequently, it might affect the accuracy and reliability of the findings.

The following limitation of this study is the teachers’ choice of teaching approach and curriculum design. In addition, the teaching materials of the subject matter used in this study were standardised, where the content of the subject matter is prohibited from major editing. Therefore, the only factor that the teachers controlled was their pedagogy applied.

**Future enhancement**

This study can be further improved with a larger sample size with greater accuracy and reliability. It also can mitigate the bias led by smaller sample size. Besides, allowing the teachers to prepare the teaching materials and the content of the subject matter on their own gives them more flexibility. The ability to design their curriculum also allows them to keep their teaching materials relevant to the latest trend and, most importantly, tailored according to their students’ needs and feedback. It also reflects a teacher’s efficacy in integrating technological tools into their teaching while their proficiency in TPACK elements is also addressed in a clearer picture.

**Ethics and consent**

All the procedures performed in this study involving human participants adhered to the ethical policies of the Multimedia University as approved by the Technology Transfer Office of Multimedia University under ethical approval number: EA0732021.

Written consent was also obtained from all individual participants involved in the study.

**Data availability**

Zenodo: TPACK MIS Dataset. https://doi.org/10.5281/zenodo.5744892.
This project contains the following underlying data:

- Dataset TPACK MIS 01122021.xlsx (The file contains two sheets. The first one contains the indicators of seven variables; TK, PK, CK, PCK, TPK, TCK, and TPACK used for framework analysis. The second sheet includes the results of students’ performance before and after using the MIS as pre-test and post-test).

Data are available under the terms of the Creative Commons Attribution 4.0 International license (CC-BY 4.0).

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Open Peer Review

Current Peer Review Status: ❓  ✔️  ✔️

Version 2

Reviewer Report 29 March 2022

https://doi.org/10.5256/f1000research.122054.r127435

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✔️ Siti Hadiati Nugraini
IT Master of Study Program, Faculty of Computer Science, Dian Nuswantoro University, Semarang, Indonesia

This article was approved because revisions to methods have been made on participants and the flow chart symbols of the integration of MIS and TPACK in the virtual classroom.

**Competing Interests:** No competing interests were disclosed.

**Reviewer Expertise:** Multimedia Innovative of Learning

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 24 March 2022

https://doi.org/10.5256/f1000research.122054.r127436

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✔️ Uchenna Cyril Eze
Division of Business and Management, Beijing Normal University & Hong Kong Baptist University United International College (BNU-HKBU United International College), Zhuhai, China

Revised version is fine. No further comments. My concerns were addressed.

**Competing Interests:** No competing interests were disclosed.
Reviewer Expertise: Information systems, MIS, e-business, e-learning, teaching and learning pedagogy, KM, marketing, business ethics

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Uchenna Cyril Eze
Division of Business and Management, Beijing Normal University & Hong Kong Baptist University United International College (BNU-HKBU United International College), Zhuhai, China

I read the manuscript titled “Synchronous Display and Whiteboard-Like Freehand Writing App as Teaching Tool for Virtual Classroom amidst the Pandemic” with great interest.

It explored the integration of technology pedagogy and knowledge content in a virtual learning environment. Specifically, it evaluates the effectiveness of teaching and learning that combines educational technology and knowledge content during the covid-19 pandemic period. The content in the manuscript was presented well, concise, highlighting relevant literature, with appropriate research design, analysis, and well-organized.

However, the manuscript lacks detail. I am not sure if this was because of the journal's requirements or the authors' choice. My view is that this manuscript will benefit from additional relevant literature to provide more detailed perspective of prior research in the area. More synthesis of prior findings and how those findings fit into the findings in this manuscript. The authors could provide additional links between the discussions/findings in this manuscript to teaching and learning frameworks. This manuscript will also benefit from a detailed discussion of the outcome of the analysis, including clear contributions to teaching and learning, and to theory/literature (if any). There should be sections of the discussion devoted to the limitations of the study and potential agenda for future research. These will help to strengthen the quality, relevance, and currency of this manuscript.

The manuscript, overall, appears well-written, however, there is the need for the authors to conduct a check on the writing quality and style to improve the overall readability and presentation in the manuscript.

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and is the work technically sound?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Partly

If applicable, is the statistical analysis and its interpretation appropriate?
Yes

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Information systems, MIS, e-business, e-learning, teaching and learning pedagogy, KM, marketing, business ethics

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 02 Mar 2022
Sook Ling Lew, Multimedia University, Ayer Keroh, Malaysia

Literature Review
Relevant literature was provided in the Literature Review section as follows:

Virtual Classroom
1. However, with the introductory of online courses, the curriculum planning gained more flexibility and openness (Blain 2019). Sometimes, students were assumed to adapt to technology instantaneously without any guidance and training because they were digital natives. However, that statement was debunked in Andrew’s study. He mentioned that the teachers and students were equally needed guidance on conducting effective communication and interaction in the online classes. From his findings, the teachers had a positive attitude regarding their interaction in the online class while the students had it otherwise. It was due to the different points of view of the teachers and students perceiving the interaction, social quality and teaching presence in the online class and blended learning. One of the teachers’ common external factors in curriculum design and planning was the lack of control. The syllabus of the subject matter could be pre-design according to particular learning outcomes. Hence, the teachers were not given complete authority in selecting more
appropria...e potential of online learning as it sacrificed the flexibility in course design. The interaction between the teachers and students in the online class was a significant limitation due to the poorly designed online course.

Interactive Whiteboard
1. As a result, the students who learned in an IWB-based instruction classroom had more interest and motivation in learning (Shi et al., 2018). Integrating IWB in the classroom allowed the teachers to alter the teaching practices with more classroom activities that support their teaching academically. However, the implementation of interactive whiteboards in the classrooms did not improve the student’s learning achievement.

Discussion
The proposed research contribution was highlighted with references in the Discussion section as follows
1. However, educational tools such as interactive whiteboards are not practical in the virtual classroom, although they offer teachers various useful features (E.Science, 2020).
2. Instead, this study addressed and mitigated those issues by gaining feedback and insights from the students’ perspectives. The students’ feedback gives a more in-depth insight allowing teachers to adjust their teaching practices and content presentation of subject matter.
3. This phenomenon explains the importance of technology selection in which the technology can be utilised (Vasodavan et al., 2019). With the proper tool, the teachers can enhance the teaching and learning experience and overcome the technology integration issues faced in the past study. A well-fitted technology for teaching practices improves students’ performance academically.
4. In short, the technology integration in this study had proven that the proficiency of a teacher’s knowledge about TPACK domains and sub-domains is essential. It affects the student’s learning outcomes and academic achievements. The use of the proposed MIS in the online class positively impacts the teaching and learning experience. In the virtual classroom, the teachers have limited choices of tools to present their content of the subject matter. On top of that, their efficacy in using technology is also varied. Hence, the proposed MIS gives the teachers an alternative way of presenting the content of the subject matter in the virtual classroom. In the meantime, their teaching techniques and practices were restructured and improved with the integration of the proposed MIS.

Limitations
Limitations section was added with the content as follows:
- There were several limitations faced in this study. One of the most significant limitations is the number of respondents for the survey distributed. In addition, the students who participated in the experiment were pre-assigned and divided into smaller tutorial groups. Hence, the sample size is considerably small. Consequently, it might affect the accuracy and reliability of the findings.
- The following limitation of this study is the teachers’ choice of teaching approach and curriculum design. In addition, the teaching materials of the subject matter used in
this study were standardised, where the content of the subject matter is prohibited from major editing. Therefore, the only factor that the teachers controlled was their pedagogy applied.

**Future Enhancement**
Future Enhancement section was added with the content as follows:
- This study can be further improved with a larger sample size with greater accuracy and reliability. It also can mitigate the bias led by a smaller sample size. Besides, allowing the teachers to prepare the teaching materials and the content of the subject matter on their own gives them more flexibility. The ability to design their curriculum also allows them to keep their teaching materials and contents of the subject matter relevant to the latest trend and, most importantly, tailored according to their students' needs and feedback. It also reflects a teacher's efficacy in integrating technological tools into their teaching while their proficiency in TPACK elements is also addressed in a clearer picture.

**Competing Interests:** No competing interests were disclosed.

Reviewer Report 02 February 2022

https://doi.org/10.5256/f1000research.77186.r118453

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Siti Hadiati Nugraini
IT Master of Study Program, Faculty of Computer Science, Dian Nuswantoro University, Semarang, Indonesia

APPROVED WITH MINOR RESERVATIONS

**Introduction - Background Section:**
The study is relevant and acceptable. However, the study should examine other related research works.

**Method Section – Overview Section:**
**Needs Analysis.**
The first step taken by researchers, before designing learning media that will be used by users, is usually to carry out the stages of analyzing user needs. This is done by making a needs analysis questionnaire which is given to users of learning media that will be used in research. So, it is hoped that the learning media used in this study are really needed by users.

**Overview, Figure 1 (Page 4)**
"Beginning of the subject in new semester" on Figure 1, usually use “Ellipse Symbol".
Note:
The elliptical shape symbol on the flowchart can be used to “START” and “END” activities.

Methods - Participants: (Page 4)
It is possible to include the number of populations involved in this study. The article only mentions the sample, the population size has not been explained.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, with reservations, as outlined above.

Please see here for a further diagram to help clarify the reviewer's suggestion about Figure 1.

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and is the work technically sound?
Partly

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Yes

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Multimedia Innovative of Learning

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Introduction - Background Section:
Related research works were examined and updated in the Introduction – Background section as follows:
1. In the Vasodavan et al. study (2020), the teachers are incompetent in incorporating
technology effectively into their lessons and activity. They do possess solid knowledge of the technology, but they can hardly fit this technology, especially into their teaching practices when it comes to integration. Hence, collaborative teaching is less effective when the teachers cannot identify the most appropriate technology to support their teaching practices. Furthermore, technology integration in education never proposed an ultimate solution but offered an alternative (Castañeda and Selwyn, 2018. Therefore, technology should not be the sole reason for being blamed as an instrumental issue. Besides, technology integration in the classroom leads to more issues or is somewhat problematic. Therefore, technology integration in education should emphasise alternativity instead of betterment in which the claim of “better technology” is very vague. The choice of technology should not consider only the latest trend but consider its functionality and suitability. There is no technology that can fit into all scenarios and criteria.

2. Moreover, the teachers are unprepared for the sudden transition to the online teaching approach. Due to the lack of experience in online classes, they are not proficient in using unfamiliar technology to conduct classroom activities that they used to in the conventional class. For example, one of the mandatory technical skills required for the online class is video conferencing with the synchronous presentation in the virtual classroom. It somehow hinders the students’ understanding of the subject matters. Furthermore, the teachers with less experience and lower efficacy with information and communication technology (ICT) tend to undergo more negativity while teaching online classes (van der Spoel et al., 2020). Their willingness of adopting technology in their teaching was mainly due to their prior experience and perceived value towards the technology integration.

Method Section – Overview Section:
The proposed mobile interactive system integrated into the study had great similarity with the conventional whiteboard and the virtual whiteboard provided by some online social platforms. In addition, the teachers used the on-screen writing feature of the proposed system as an alternative for the conventional whiteboard. Hence, the teachers could replicate the conventional teaching and learning experience into the virtual classroom. Hence, additional information was added in the study at Method – Overview as follows:

- Besides, a pilot study was conducted to gather feedback and insights from the students and experts before conducting the actual survey. The findings of the pilot study indicated that the users were showing a positive attitude towards the integration of the proposed MIS as learning media.

Overview, Figure 1 (Page 4)
Figure 1 was updated in the Overview section with Ellipse Shape Symbol for ‘Beginning of the subject in new semester’ instead of rounded-edge rectangle shape.

Methods - Participants: (Page 4)
The population info regarding the participants of the study was updated in the Method – Participants section as follows:

- Online questionnaires are distributed to 45 Malaysian private university students enrolling in “Knowledge Management”.

Competing Interests: No competing interests were disclosed.

Reviewer Report 05 January 2022

https://doi.org/10.5256/f1000research.77186.r118452

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Dalbir Singh
Universiti Kebangsaan Malaysia, Bangi, Malaysia

Introduction - Background Section:
The study is relevant and acceptable. However, the need for such a study should be precisely justified. The study should examine other related research works. A critical review of approaches exploited in other studies should be performed to enhance the overall contribution further.

Introduction - Problem Statement Section:
Add more references that support the main issue in the study. Justify the selection of the main issue compared to other issues pertaining to teaching tools for a virtual classroom.

Method Section – Overview Section:
Justify the selection and formulation of the approach as illustrated in Figure 1. Review relevant studies that use a similar approach.

Discussion Section:
Review the research contribution against other research works. How different is the proposed research contribution? Add references.

Is the work clearly and accurately presented and does it cite the current literature?
Partly

Is the study design appropriate and is the work technically sound?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Yes

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Partly

**Competing Interests:** No competing interests were disclosed.

**Reviewer Expertise:** Human-Computer Interaction, Impact Study & Strategic Planning, E-Learning Technology, Quality Assurance

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

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**Introduction - Background Section:**
Related research works were examined as follows:

1. In the Vasodavan et al. study (2020), the teachers are incompetent in incorporating technology effectively into their lessons and activity. They do possess solid knowledge of the technology, but they can hardly fit this technology, especially into their teaching practices when it comes to integration. Hence, collaborative teaching is less effective when the teachers cannot identify the most appropriate technology to support their teaching practices. Furthermore, technology integration in education never proposed an ultimate solution but offered an alternative (Castañeda and Selwyn, 2018). Therefore, technology should not be the sole reason for being blamed as an instrumental issue. Besides, technology integration in the classroom leads to more issues or is somewhat problematic. Therefore, technology integration in education should emphasise alternativity instead of betterment in which the claim of “better technology” is very vague. The choice of technology should not consider only the latest trend but consider its functionality and suitability. There is no technology that can fit into all scenarios and criteria.

2. Moreover, the teachers are unprepared for the sudden transition to the online teaching approach. Due to the lack of experience in online classes, they are not proficient in using unfamiliar technology to conduct classroom activities that they used to in the conventional class. For example, one of the mandatory technical skills required for the online class is video conferencing with the synchronous presentation in the virtual classroom. It somehow hinders the students’ understanding of the subject matters. Additionally, the teachers with less experience and lower efficacy with information and communication technology (ICT) tend to undergo more negativity while teaching online classes (van der Spoel et al., 2020). Their willingness of adopting technology in their teaching was mainly due to their prior experience and perceived value towards the technology integration.

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**Introduction - Problem Statement Section:**
Supportive references were added in the Introduction – Problem Statement section as follows:

1. The practice of conducting classes through the virtual classroom sacrifices the benefits experienced in the conventional classroom environment. It negatively affects the students’ knowledge acquisition of the subject matters from their teachers (Coman et al., 2020).

2. Although teachers nowadays are primarily aware of and understand the nature of technology and its functionality, they commonly face challenges in integrating the technology effectively into their pedagogy (Vasodavan et al., 2019).

**Method Section – Overview Section:**
The selection and formulation of the approach illustrated in Figure 1 were justified in the Methods – Overview section as follows:

- The experiment is designed based on a quasi-experiment. It consists of pre-test and post-test of an experimental group. The pre-test and post-test of the knowledge checking test share similar intentions of the test conducted by Mustafa and Meric (2019) on learning achievement. As for the pre-test and post-test of TPACK, assessments are conducted to observe whether the difference is significant regarding the teachers’ improvement in TPACK knowledge domains’ understanding (Kartal and Dilek, 2021).

**Discussion Section:**
The proposed research contribution was highlighted with references in the Discussion section as follows:

1. However, educational tools such as interactive whiteboards are not practical in the virtual classroom, although they offer teachers various useful features (E.Science, 2020).

2. Instead, this study addressed and mitigated those issues by gaining feedback and insights from the students’ perspectives. The students’ feedback gives a more in-depth insight allowing teachers to adjust their teaching practices and content presentation of subject matter.

3. This phenomenon explains the importance of technology selection in which the technology can be utilised. With the proper tool, the teachers can enhance the teaching and learning experience and overcome the technology integration issues faced in the past study (Vasodavan et al., 2019). A well-fitted technology for teaching practices improves students’ performance academically.

4. In short, the technology integration in this study had proven that the proficiency of a teacher’s knowledge about TPACK domains and sub-domains is essential. It affects the student's learning outcomes and academic achievements. The use of the proposed MIS in the online class positively impacts the teaching and learning experience. In the virtual classroom, the teachers have limited choices of tools to present their content of the subject matter. On top of that, their efficacy in using technology is also varied. Hence, the proposed MIS gives the teachers an alternative way of presenting the content of the subject matter in the virtual classroom. In the
meantime, their teaching techniques and practices were restructured and improved with the integration of the proposed MIS.

Competing Interests: No competing interests were disclosed.

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