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Exploring the Influence of Problematic Mobile Phone Use on Mathematics Anxiety and Mathematics Self-Efficacy: An Empirical Study during the COVID-19 Pandemic

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Abstract: Problematic mobile phone use is a pervasive issue globally and has aroused wide public concerns. Prior studies have indicated that problematic mobile phone use has a series of negative effects on individuals' physical and mental health. However, the effects on student learning have seldom been investigated. During the COVID-19 pandemic, home quarantine and social distancing have led to individuals' greater problematic mobile phone use, and it is essential to have a better understanding of individuals' problematic mobile phone use and its negative effects during this unprecedented period. Given this, the present study investigates the effects of university students' problematic mobile phone use on mathematics self-efficacy and mathematics anxiety, which play critical roles in mathematics learning. This study collected data from 420 students in March 2022, when a large-scale COVID-19 lockdown took place in Shanghai, China. Structural equation modeling was used to analyze the data. Our findings show that university students' problematic mobile phone use can significantly impact mathematics anxiety and indirectly—yet considerably—influence mathematics self-efficacy. This study calls for increased public concern regarding students' problematic mobile phone use during the COVID-19 pandemic.

Keywords: COVID-19 pandemic; mathematics anxiety; mathematics self-efficacy; problematic mobile phone use

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1. Introduction

Problematic mobile phone use is a pervasive issue globally, which has aroused wide public concerns [1,2]. It has been reported that "10.5% of adolescents are problematic mobile phone users, and 20.5% are potential problematic users" [2] (p. 301). Prior studies have indicated that problematic mobile phone use has a series of negative effects on individuals' physical and mental health [3–5]. During the COVID-19 pandemic, it was reported that home quarantine and social distancing have led to individuals' greater problematic mobile phone use [6,7]. Specifically, the COVID-19 lockdown has significantly influenced people psychologically [7], including causing loneliness [8,9], passion [10], fear [10], and anxiety [11,12]. Facing psychosocial problems in the real world, people are very likely to use mobile phones to escape negative feelings by immersing themselves in the virtual world [7,13]. Given this, it is necessary to develop a better understanding of individuals' problematic mobile phone use and its negative effects during this unprecedented period.

During the COVID-19 pandemic, most university students must continue their

studies with e-learning platforms [14,15]. During the COVID-19 pandemic, university students are likely to spend more time on mobile phones than usual. There are two possible reasons for this. On the one hand, as aforementioned, by using mobile phones, students can escape the negative emotions (e.g., anxiety, loneliness, fear, boredom, passion, etc.) caused by the COVID-19 lockdown. On the other hand, in physical classrooms, teachers can effectively supervise students not to use mobile phones in class. However, students may use mobile phones to do other things instead of listening to the lectures during online class sessions due to the absence of adequate supervision by teachers on the e-learning platforms. Therefore, the proportion of potential problematic mobile phone users will be larger. University students' greater problematic mobile phone use may further negatively impact their academic learning. However, it is pointed out that most existing studies have examined the negative effects of problematic mobile phone use on adolescents' psychological factors (e.g., depression, fear of missing out, and distress) [16–19] and the effects on student learning have seldom been investigated [20]. Therefore, more research is needed to explore the impact of university students' problematic mobile phone use on their learning.

Motivated by these gaps, this study aims to investigate the effects of university students' problematic mobile phone use on their learning of mathematics, which is one of the main subjects at the university level, and almost all university students in China must learn. Particularly, two factors are selected as the dependent variables, namely mathematics self-efficacy and mathematics anxiety, which play crucial roles in mathematics learning [21,22]. This study contributes to the limited understanding of the negative effects of problematic mobile phone use on student learning and calls for more concern on university students' problematic mobile phone use during the COVID-19 pandemic.

2. Literature Review and Hypotheses Development

Problematic mobile phone use can be defined as "a phenomenon related to maladaptive mobile phone use, which could present a pattern of dependency involving negative consequences (e.g., using the mobile phone excessively during daily activities ignoring consequences or harm, being unable to maintain concentration in a task or an interpersonal relationship due to the need to check mobile phone notifications constantly)" [23] (p. 276). To make it easier, problematic mobile phone use can also be understood as the phenomenon that individuals "are prone to use their phones excessively probably due to some pre-existing factors which encourage the person to go on to use" regardless of "the possible negative consequences of mobile phone use" [24] (p. 821). According to the control-value theory [25,26], the process of learning activities will be influenced by situational contexts. A problematic situation (e.g., problematic mobile phone use) may negatively impact students' learning in many aspects, including anxiety and self-efficacy [27].

It is found that mathematics anxiety is "one of the common attitudinal and emotional factors that have received attention in recent years." [28] (p. 1326). Specifically, mathematics anxiety can be defined as "the presence of a syndrome of emotional reactions to arithmetic and mathematics" [29] (p. 344). The control-value theory posits that students' anxiety is usually impacted by situation states [25–27], such as problematic mobile phone use. A recent study has also confirmed that primary school students' problematic mobile phone use will directly increase their mathematics anxiety [27]. However, such a relationship has rarely been examined at the university level. Hence, our first hypothesis is as follows:

Hypothesis 1 (H1). *University students' problematic mobile phone use will directly impact their mathematics anxiety.*

Mathematics self-efficacy is "one's belief about how their own action and effort could lead to success in mathematics" [30] (p. 2). The control-value theory claims that self-efficacy, as one of the most important action-control expectancies, will be affected by individuals' learning environments (i.e., situational contexts) [25]. Therefore, it can be assumed that unsupportive or unfavorable learning environmental factors (e.g., problematic mobile phone use) will decrease students' mathematics self-efficacy. However, the impact of problematic mobile phone use on subject-specific self-efficacy has scarcely been confirmed. Hence, we propose our second hypothesis:

Hypothesis 2 (H2). *University students' problematic mobile phone use will directly impact their mathematics self-efficacy.*

As for the two dependent variables, namely mathematics self-efficacy and mathematics anxiety, previous research has also substantiated their negative correlations [30–33]. For instance, a study in the USA found that middle school students' mathematics anxiety negatively impacted their mathematics self-efficacy [31]. Likewise, the direct influence of mathematics anxiety on mathematics self-efficacy has also been verified among first-year undergraduate students in the USA [32] and deaf children in China [33]. Hence, we propose our third hypothesis:

Hypothesis 3 (H3). *University students' mathematics anxiety will directly impact their mathematics self-efficacy.*

3. Materials and Methods

3.1. Data Collection Tool

Our data collection tool was a combination of three seven-point Likert scales. The first scale was adapted from [34] to measure students' problematic mobile phone use. Although this scale was developed in South Korea, it has also recently been validated in the Chinese context [27]. This scale consisted of four subdomains (i.e., disturbance of adaptive functions, virtual life orientation, withdrawal and tolerance) with a total of fifteen items (i.e., PMU1-PMU15). If a participant received high points in all the items of the first scale, they might suffer from greater problematic mobile phone use. If a participant received low points in all the items of the first scale, they might not suffer from problematic mobile phone use. The second scale was adapted from [35] to measure students' mathematics self-efficacy. This scale consisted of five items (i.e., MSE1-MSE5). The third scale was adapted from [36] to measure students' mathematics anxiety. This scale consisted of four items (i.e., MA1-MA4). Our data collection tool consisted of twenty-four items. Table 1 shows the details of our data collection tool.

Table 1. The details of our data collection tool.

Construct	Item	Description
Problematic mobile phone use	PMU1	My grades dropped due to excessive mobile phone use.
	PMU2	I have a hard time doing what I have planned (study, do coursework, or go to afterschool classes) due to using mobile phone.
	PMU3	People frequently comment on my excessive mobile phone use.
	PMU4	Family or friends complain that I use my mobile phone too much.
	PMU5	My mobile phone distracts me from my

		studies.
	PMU6	Using a mobile phone is more enjoyable than spending time with family or friends.
	PMU7	When I cannot use a mobile phone, I feel like I have lost the entire world.
	PMU8	It would be painful if I am not allowed to use a mobile phone.
	PMU9	I get restless and nervous when I am without a mobile phone.
	PMU10	I am anxious when I am without a mobile phone.
	PMU11	I panic when I cannot use my mobile phone.
	PMU12	I try cutting my mobile phone usage time, but I fail.
	PMU13	I cannot control my mobile phone usage time.
	PMU14	Even when I think I should stop, I continue to use my mobile phone too much.
	PMU15	Spending a lot of time on my mobile phone has become a habit.
Mathematics self-efficacy	MSE1	I expect to do as well as or better than other students in the mathematics courses.
	MSE2	I am confident I will do well on mathematics assignments and projects.
	MSE3	I believe I can master the knowledge and skills in the mathematics courses.
	MSE4	I am confident I will do well on mathematics tests.
	MSE5	I believe I can earn good grades in the mathematics courses.
Mathematics anxiety	MA1	I often worry that it will be difficult for me in the mathematics courses.
	MA2	I get very tense when I have to do mathematics coursework.
	MA3	I get very nervous doing mathematics problems.
	MA4	feel helpless when doing a mathematics problem.

3.2. Data Collection

We had obtained approval from the research ethics committee before our data collection. This study collected data in March 2022, when a large-scale COVID-19 lockdown was taking place in Shanghai, China. We randomly selected twenty teachers at two universities in Shanghai. We invited them to share the recruitment information with their students through learning management systems (for the features of the learning management systems used in the two universities, see [14,15]). Students willing to participate in our study could click the questionnaire link in the learning management systems and fill in the survey questionnaires anonymously online. This study did not collect any information that may lead to the identification of our participants.

3.3. Participants

A total of 462 students from two universities in Shanghai, China, were recruited for this study. However, 42 students did not fill in their survey questionnaires completely. Therefore, their responses were removed. A total of 420 students' responses were included in the formal data set. Among them, 46% were male students, and 54% were female students. As for the students' majors, 35% were STEM (science, technology, engineering, and mathematics), while 65% were non-STEM (e.g., history, education, management, economics, etc.).

3.4. Data Analysis

Structural equation modeling was used to analyze the data [37]. We first validated our instrument by testing the measurement model. Next, we examined the effects of problematic mobile phone use on mathematics anxiety and mathematics self-efficacy by testing the structural model. Our data analysis was performed with the help of the software named IBM SPSS AMOS 22.

Following the guidance of structural equation modeling analysis [38,39], our study selected several indices to help evaluate the model fit, including the comparative fit index (CFI), the Tucker–Lewis Index (TLI), and the root mean square error of approximation (RMSEA). A model could be considered to fit the data well if CFI > 0.90, TLI > 0.90, RMSEA < 0.08 [38,39].

4. Results

4.1. The Results of the Measurement Model

Considering that the construct of problematic mobile phone use has four subdomains (i.e., disturbance of adaptive functions, virtual life orientation, withdrawal and tolerance) [34], we first estimated the four-factor measurement model and the second-order factor with its fifteen items (i.e., PMU1-PMU15). As for the four-factor measurement model, the modification indices of AMOS output illustrated that PMU3, PMU4, PUM5, PMU8, and PMU9 were largely correlated with other items, showing that there existed multicollinearity. Hence, we had to isolate these five items from the measurement model. The re-specified four-factor measurement model contained ten valid items and fitted the data well [38,39], with $\chi^2 = 62.889$, $df = 29$, $p = 0.000$, CFI = 0.994, TLI = 0.991, and RMSEA = 0.053. As for the second-order factor, namely problematic mobile phone use, the AMOS output showed that the four first-order factors significantly impacted it. To be specific, problematic mobile phone use can be assessed by disturbance of adaptive functions ($\beta = 0.71$, $p = 0.000$), virtual life orientation ($\beta = 0.86$, $p = 0.000$), withdrawal ($\beta = 0.87$, $p = 0.000$), and tolerance ($\beta = 0.92$, $p = 0.000$). This confirmed that disturbance of adaptive functions, virtual life orientation, withdrawal and tolerance were four first-order factors of problematic mobile phone use.

We then integrated this valid second-order factor (i.e., problematic mobile phone use) with the remaining nine items (i.e., MA1-MA4 and MSE1-MSE5) to test the three-factor measurement model of problematic mobile phone use, mathematics self-efficacy and mathematics anxiety. The AMOS output illustrated that MSE1 and MSE5 were largely correlated with other items, showing the existence of multicollinearity. After isolating these two items, the three-factor measurement model fitted the data well [38,39], with $\chi^2 = 347.550$, $df = 112$, $p = 0.000$, CFI = 0.977, TLI = 0.972, and RMSEA = 0.071.

Table 2 summarized the mean (M), standard deviation (SD), and factor loadings (FL) for each item and Cronbach's alpha for each construct. All Cronbach's alphas exceeded 0.7, which indicated that our research instruments' reliability was satisfactory [40,41].

Table 2. Mean (M), standard deviation (SD), and factor loadings (FL) for each item and Cronbach's alpha for each construct.

Construct	Item	M	SD	FL	Cronbach's Alpha
disturbance of adaptive functions	PMU1	4.32	1.76	0.94	0.957
	PMU2	4.26	1.76	0.98	
virtual life orientation	PMU6	3.57	1.84	0.85	0.878
	PMU7	3.89	1.83	0.92	
withdrawal	PMU10	3.81	1.82	0.95	0.982
	PMU11	3.82	1.83	0.98	
tolerance	PMU12	3.81	1.77	0.95	0.971
	PMU13	3.87	1.76	0.97	
	PMU14	3.86	1.78	0.97	
	PMU15	4.03	1.77	0.89	
mathematics anxiety	MA1	4.82	1.92	0.88	0.972
	MA2	4.38	1.94	0.97	
	MA3	4.36	1.96	0.99	
	MA4	4.33	2.03	0.95	
mathematics self-efficacy	MSE2	5.71	1.43	0.95	0.970
	MSE3	5.67	1.45	0.98	
	MSE4	5.55	1.52	0.95	

As for the validity of our research instrument, we first calculated the values of composite reliability (CR) and the average variance extracted (AVE). As shown in Table 3, the values of CR for all three factors were above 0.7, and the values of AVE were above 0.5. This indicated that the convergent validity of our research instrument was satisfactory [39–41]. Next, we checked and confirmed that the square roots of the AVEs were larger than the correlations. Therefore, the discriminant validity of our research instrument was acceptable [42].

Table 3. The convergent validity results.

Factor	CR	AVE
problematic mobile phone use	0.91	0.71
mathematics anxiety	0.97	0.90
mathematics self-efficacy	0.97	0.92

4.2. The Results of the Structural Model

Figure 1 shows the results of the structural model. The AMOS output indicated that it fit the data well [38,39], with $\chi^2 = 347.550$, $df = 112$, $p = 0.000$, CFI = 0.977, TLI = 0.972, and RMSEA = 0.071. The results showed that problematic mobile phone use had significant impact on mathematics anxiety ($\beta = 0.41$, $p = 0.000$), and mathematics anxiety had significant impact on mathematics self-efficacy ($\beta = -0.14$, $p = 0.012$). Hence, Hypothesis 1 and Hypothesis 3 were supported. Hypothesis 2 was not supported as the direct impact of problematic mobile phone use on mathematics self-efficacy ($\beta = 0.10$, $p = 0.070$) was not significant. Despite this, we detected that problematic mobile phone use had a significant indirect impact on mathematics self-efficacy ($\beta = -0.057$, $p = 0.022$).

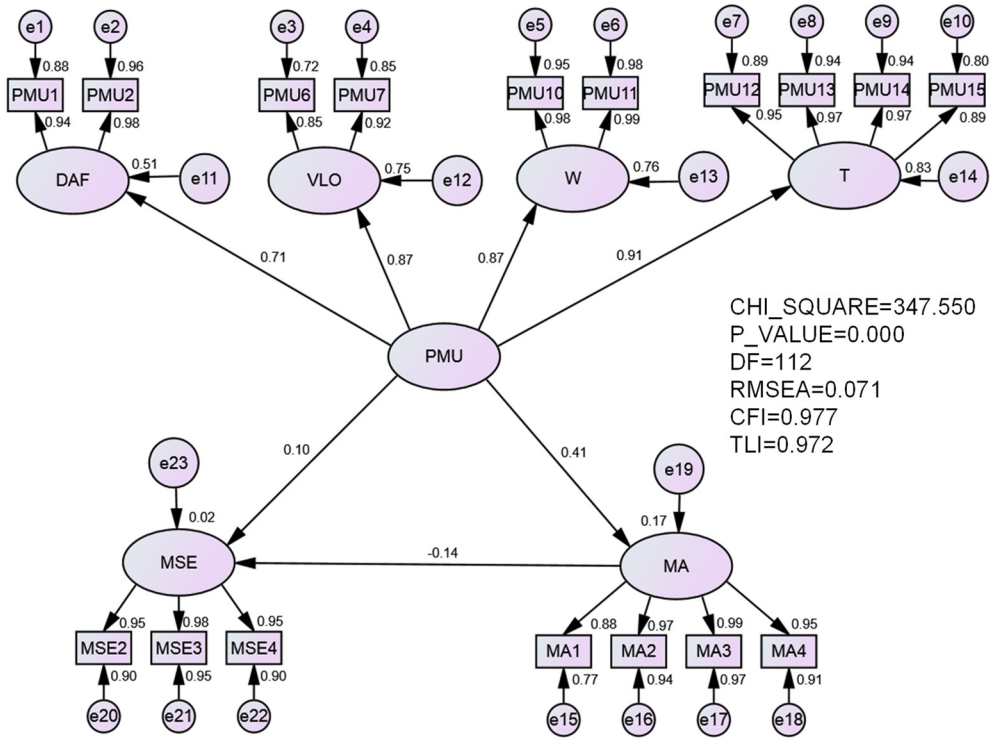

Figure 1. The results of the structural model.

5. Discussion

During the COVID-19 lockdown, individuals are more likely to suffer from problematic mobile phone use [6,7], negatively affecting their physical and mental health [3–5]. However, very few studies have paid attention to the adverse effects of problematic mobile phone use on university students' academic learning [20], especially during this unprecedented period. Furthermore, few studies have examined the relationships between university students' problematic mobile phone use and their subject-specific learning [27]. Since mathematics plays a significant role in many education systems, it is essential to explore the links between problematic mobile phone use and mathematics learning [27]. Therefore, the goals of this current study include examining the negative effects of university students' problematic mobile phone use on their mathematics learning. This study has important theoretical contributions and practical implications.

This study confirms the direct influence of university students' problematic mobile phone use on mathematic anxiety, which is in line with previous studies [27]. Our findings also support the control-value theory, which claims that students' anxiety is usually impacted by situation states [25–27]. However, this study did not detect the direct impact of problematic mobile phone use on mathematic self-efficacy. This implies that self-efficacy may not be directly affected by individuals' problematic mobile phone use, which is one of the learning environmental factors. This is not in line with the control-value theory [25]. In addition, our findings support the negative correlations between mathematics anxiety and mathematics self-efficacy at the university level, which has frequently been found in prior studies [30–33]. Most importantly, this current study is the first to confirm the indirect negative impact of problematic mobile phone use on mathematic self-efficacy. This expands the existing knowledge of the negative effects of problematic mobile phone use on students' learning.

As for the practical implications, this study suggests that mathematics teachers should pay more attention to students' mobile phone use. Considering the impact of problematic mobile phone use on mathematics anxiety and self-efficacy, mathematics teachers should help students realize the risks of excessive use of mobile phones. It is also

a good idea to invite students' parents to monitor their mobile phone use during the COVID-19 lockdown.

This study has several limitations. First, we only examined the negative influence of university students' problematic mobile phone use on two dependent variables (i.e., mathematics self-efficacy and mathematics anxiety), which play vital roles in mathematics learning [21,22]. However, mathematics learning contains many additional aspects not involved in this study. Future research can include more variables (e.g., mathematics achievement, mathematics interest, mathematical thinking skills, etc.). Second, our study only explored the negative influence of university students' problematic mobile phone use on their mathematics learning. Considering the close connections among science, technology, engineering and mathematics [43], it can be assumed that university students' problematic mobile phone use may also have negative effects on their science, technology and engineering learning. However, more research is needed to confirm this. Third, our participants were from two universities in Shanghai, China, while other universities in rural areas of China were not included. Further studies can include more students to cover these rural universities.

6. Conclusions

This study explores the influence of university students' problematic mobile phone use on mathematics anxiety and mathematics self-efficacy during the COVID-19 pandemic. Our findings show that university students' problematic mobile phone use can impact mathematics anxiety directly, and mathematics anxiety can impact mathematics self-efficacy directly. Despite the direct impact of problematic mobile phone use on mathematics self-efficacy is not significant, problematic mobile phone use can indirectly influence mathematics self-efficacy significantly. This study focuses on the negative effects of university students' problematic mobile phone use on their subject-specific academic learning, which have seldom been discussed in prior studies. Considering the problematic mobile phone use caused by home quarantine and social distancing [6,7], this study calls for more public concern regarding mobile phone use during the COVID-19 pandemic.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Institutional Review Board of Shanghai Jian Qiao University.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

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