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Pupils' Learning Characteristics, Self-directed Learning Ability, and Mathematical Ability by Applying a Gamified Math Platform for Distance Learning

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Abstract: This study aims to examine a remote primary school teacher who collaborated with 42 university volunteer mentors by applying gamified mathematics platform "Math-Island" for distance learning to facilitate third-grade pupils' self-directed learning (SDL) and mathematical ability. This study uses Wilcoxon tests to analyze 21 weeks of Math Island learning data and mathematics abilities tests, and content analysis of 21 verbatim transcripts of teaching review meetings and 203 teaching records as evidence of the learning characteristics and the progress of pupils' self-directed learning ability. The result found that the pupils' learning characteristics related to volunteer mentors' teaching, classmates, and their own learning attitudes. The pupils under distance learning gradually developed their self-directed learning abilities in the second semester. Besides, the post-test of mathematics learning ability has improved significantly compared with the pre-test. Recommendations for future research are also presented at the end of this paper.

Keywords: Distance learning, Self-directed learning, Mathematical learning, Online mentor, Math Island

1. Introduction

The COVID-19 pandemic has shifted distance learning increasingly common in lives throughout the world (Fidalgo, Thormann, Kulyk, & Lencastre, 2020). Education is facing a difficult time, but also encountering a new opportunity. In remote schools, pupils often lack enough cultural stimulation and learning resources. During the COVID-19 pandemic, distance learning is necessary to be a good approach. Pupils can learn new knowledge by watching videos, such as massive open online courses (MOOCs), or by using digital technology to complete some questions after watching videos, such as online learning platforms like Khan Academy to support their learning process (Thompson, 2011; Vidergor & Ben-Amram, 2020). Individuals who learned and were responsible for their own planning, implementing, and evaluation of the effort were indicated as self-directed learning (SDL, Hiemstra,1994).

Distance learning students usually showed greater SDL (Khalid, Bashir, & Amin, 2020), and SDL may lead to successful learning performance. When students adopt distance learning, they may progress in structured learning without teachers' supervision (Zhu et al, 2022), but the critical point is using effective online learning platforms to do SDL. A well-structured learning platform can supplement students' learning information and help them pursue knowledge at their speed, engaging in the learning through immediate feedback. Previous studies had confirmed that timely and frequent feedback may contribute to online learners' performance (Goldsmith, 2014), while gamified learning platforms have a complete learning structure to increase students' learning interest and motivation (Yeh et al, 2019). Besides, the teacher can receive mentors' feedback and online log data to integrate the pupils' self-assessment features and ensure that pupils are properly engaged in learning (Schneider, & Council, 2021). Hence, to develop remote school pupils' SDL and improve their mathematical abilities, applying a gamified platform to support pupils' distance learning may be a good choice.

When pupils learn math under one-to-one distance learning with mentors' guidance may enhance their learning effect, but can pupils thus develop their SDL is still a question. According to the reasons above, a class teacher collaborated with volunteer mentors by applying the Math-Island to support the mentors' guidance for enhancing remote school pupils' mathematical learning and to see if

those pupils can foster their SDL ability through distance learning. Therefore, this study proposes three research questions as follows.

(1) What are the learning characteristics when pupils used the gamified learning platform for distance learning with the mentors' help?

(2) Can pupils develop self-directed learning abilities after using the gamified learning platform for distance learning with the mentors' help?

(3) Can "using the gamified mathematics platform for distance learning "improve the pupils' mathematics learning ability?

2. Methods

2.1 Research Design

This study conducted two sessions of distance learning once a week, each session is 40 minutes. The first semester had thirteen times of distance learning, while the second semester had ten times of distance learning. Before distance learning, a pre-test was conducted to understand the pupils' learning basis, and a post-test was also conducted at the end of the distance learning.

Pupils had to learn the Math-Island tasks the class teacher assigned. However, if some pupils learned faster, they could choose the learning tasks they felt interested, or go shopping the building on Math-Island. The volunteer mentors only taught the pupils when they made at least two mistakes. If the pupils were still wrong, the mentors may ask the pupils some questions as guidance or demonstrate how to solve word problems. If the pupils do not make mistakes, the mentors may just stand aside without giving any learning help in order to develop the pupils' SDL ability.

2.2 Participants

The participants in this study were a third-grade class teacher and all students, only 10 pupils (6 boys and 4 girls) from a remote primary school in northern Taiwan. There were 42 public university students who signed up online and volunteered to serve as online math mentors (6 males and 17 females in the first semester and 9 males and 10 females in the second semester), of which 16 volunteer mentors participated in more than half of service times, while 11 volunteer mentors only participated once.

Due to the Covid-19 pandemic, the third-grade students used the Math-Island platform to study during the after-school caring time. The mentors help pupils learn mathematics through one-to-one distance learning. The mentors played the role of asking mathematical questions rather than direct teaching instructors to scaffold the pupils' mathematical concepts and problem-solving, the pupils may thus internalize those mathematics questions into their learning and do mathematics correctly (Mason, 2000). The class teacher was responsible for the class order and solving the technological problems. She rarely intervened in mentors' instruction.

2.3 Implement Tools: Math-Island and Google Meet

In this study, pupils used the "Math-Island" to learn and practice mathematics. "Math-Island" is a gamified mathematics learning platform developed based on the curriculum guidelines in the mathematics field of the Taiwan Ministry of Education. It covers primary school mathematical concepts from first to sixth grades, which are presented through animated teaching videos and interactive games. Students can learn the mathematical concepts by themselves according to the guidance of concept maps.

After students complete the math tasks, the system would give corresponding rewards and feedback according to the correct answer rate, and the learning results can be transformed into a visual building appearance based on the correct answer rate and task completion rate. Besides, pupils can earn money and labor from completing math tasks to buy their buildings or ships. Pupils may plan and manage their learning by completing the mathematics tasks continuously to create the appearance of their island, and gradually accumulate their foundation of mathematics concepts, thereby improving their confidence and interest in mathematics learning. The class teacher can check pupils' learning history records to understand their learning progress and difficulties.

Each pupil used the online communication software Google Meet for one-to-one distance learning. The pupils needed to share their screen so that the volunteer mentor can see their learning task picture in Math Island, and the pupils can also see the teaching screen of the volunteer mentors in the same way.

2.4 Data Collection and Analysis

The purpose of this research is to explore the pupils' learning characteristics of using the Math Island learning platform for distance learning, whether volunteer mentors using the gamified mathematics platform for distance learning" enhance pupils' task numbers and correct rates, develop self-directed learning mode, as well as the mathematics learning progress. Four types of research materials were used to collect and analyze pupils' data in this study.

(1) LMS dashboard and log data: the LMS dashboard and log data on Math-Island were used to understand the pupils' learning characteristics, their correct rate, and the amount of learning tasks. The pupils' SDL ability means the number of learning tasks in which pupils kept their learning tasks on Math Island after distance learning without the class teacher assigning tasks.

(2) Transcripts of the briefing: in the teaching briefing, the online mentors would report students' learning performance and how they taught students that day. The teacher would provide feedback. Those processes were videotaped and transcribed to help understand pupils' learning characteristics.

(3) Teaching guidance records: the volunteer mentors had to fill out the teaching guidance record sheet after every teaching to help the class teacher understand students' myth concepts. This sheet was designed according to Bloom's (1956) teaching objectives and was divided into the cognitive, affective, and psychomotor domains. In other words, the volunteer mentors were invited to evaluate pupils' knowledge, learning attitudes, and skills in distance learning, the teaching strategies of volunteer mentors, as well as students' learning responses through online learning interaction. This document was used to analyze the mentors' teaching and the characteristics of pupils' learning behaviors.

(4) Pre-and post-test: This study uses the scores of " Test of Children Mathematics Achievement " developed by Xie (2014) as the pre and post-test tool to evaluate pupils' math learning ability and improvement individually. Pupils can listen to the explanation in the sample questions demonstration without reading long sentences during the test. The pupils listened to the question and replied with their answers in oral and written form. This standard test has 120 items. It targets intuitive mathematics and the law of mathematics, including zero concepts, addition concepts, carrying concepts and addition and subtraction, subtraction concepts, multiplication concept, division concepts, and mental arithmetic number lines for nine categories. Pupils who answer one question correctly can get one point. The internal consistency reliability coefficient of the test is .97, and the inter-rater reliability is above .90.

The study utilized three statistical analyses: descriptive analysis, Wilcoxon signed-rank test, and Pearson Correlation. All data were analyzed by using SPSS version 28 (SPSS Inc., Chicago, IL, USA). A Wilcoxon signed-rank test was used for analyzing pupils' learning tasks and correct rate, and pre and post-test scores for differences between the means in different periods and between SDL and distance learning. The Pearson Correlation was used to examine the relationship between math tasks and mathematical ability in post-test as the pupils' learning improvement. In addition, content analysis was used to analyze the qualitative data, such as meeting transcripts, and individual guidance records as supplement evidence of pupils' learning characteristics.

3. Result

3.1 Pupils' Learning Characteristics

This study intends to explore the learning characteristics of pupils who apply Math-Island for distance learning. The following introduces the number of math tasks the pupils completed, game engagement, and peers' influence.

As for the number of math tasks, the result shows that there are great differences among each pupil's learning task numbers. The pupils' average number of whole tasks is 219.7(SD=128.53). The pupil with the fewest participation did not have SDL, so she only did 82 math tasks, while the pupil

who had SDL and did the most math tasks is 449 tasks. Almost all pupils concentrated on the tasks of the third grade (M=107.3, SD=52.25) and the second grade (M=77.40, SD=48.66). However, the pupil with learning disabilities in the class mainly did the math tasks of the first and second grades, and only did four tasks of the third grade.

In addition, pupils rarely completed all tasks their teacher assigned during distance learning. the class teacher usually assigned pupils those math tasks below the third grade, so that pupils did fewer math tasks over the third grade. Only two high-achieving students completed tasks quickly and did nineteenth fourth-grade tasks and one task in fifth- and sixth-grade respectively.

Most pupils spend much more time when they encounter difficult mathematical concepts, such as fractions or two-step addition, multiplication, subtraction, and multiplication. Besides, pupils usually encounter difficulties with multiple-choice questions. A volunteer teacher indicated that "*When the student encounters a question with four options, he feels very annoying and doesn't want to read it.*" (MR121005CT), so the error rate is extremely high.

Although this study adopts the gamified learning platform for distance learning, students pay more attention to the math tasks the teacher assigned rather than playing games on Math-Island. Pupils usually buy new buildings and ships after or before the learning tasks. But the gameplay time decreased as time went by. And a special pupil did have any behaviors of gameplay. Only one pupil was interested in decorating her island. She can complete thirty math tasks to make money and change her buildings in her SDL. Her mentor encourages her to have more motivation in doing math tasks by using the strategy: "*Intersperse the questions with breaks, let her go to the Math-Island to buy things. She would come back and continue to do the math tasks for making money.*" (MR120307CT)

During distance learning, pupils may observe classmates' learning and compare mutual learning progress. A volunteer mentor responded that "*Ann saw that a high-achieving student in the class, Bob, solve the math island problems quickly. He would be a little impatient, and sometimes even asked Bob the answer.*" (MR120310CT) In other words, classmates' learning speed may put stress on pupils. Besides, the pupils would like to have the same teaching methods and tools as their classmates. The volunteer mentor mentioned that "*the pupils saw another volunteer mentor using small painters to teach her classmate, and she hoped I can use the same small painters to teach her.*" (MR120310CT)

3.2 Pupils' Task Amount and Correct Rates

This study investigates whether the pupils with those volunteer mentors' help can increase their correct rate in doing math tasks on Math-Island. Wilcoxon signed-rank test was used for comparing pupils' average math tasks for two different learning conditions, the number of math tasks of distance learning and the correct rate of SDL. The ranked pupils' mean number of math tasks in applying the gamified math platform for distance learning (6.43) had higher than the pupils in the SDL (3.44), which was also statistically significant (Z =-2.395, $p=.017< .05$). These results indicate that pupils in distance learning with volunteer mentors' help can do more math tasks than they were in the SDL.

However, the volunteer mentor does not always speed up the pupils' learning. Sometimes the volunteer mentors may slow down the progress of the pupils' learning tasks when they evaluated that pupils do not understand certain mathematical concepts. The mentors may intend to explain and clarify students' mathematical concepts a whole course time on one math concept. Some volunteer mentors ask pupils to understand certain math concepts completely then they can go to the following math tasks causing pupils to spend too much time on one problem and do very few problems in total.

Therefore, this study also investigates whether the pupils with those volunteer mentors' help can raise pupils' correct rate in doing math tasks on Math Island. This study uses Wilcoxon signed-rank test as the statistical technique to compare the pupils' correct rate in the second semester for two different learning conditions, the correct rate of distance learning and the correct rate of SDL. The ranked mean scores (92.98) of the correct rate of the pupils in applying the gamified math platform for distance learning is significantly higher than that of SDL (85.56), Wilcoxon signed-rank test, Z =-2.490, $p < 0.05$. These results indicate that pupils in distance learning with volunteer mentors' help had a better correct rate than they were in SDL

According to the first author's participation observation and volunteer, mentors reflect their teaching in the teaching review meeting and guidance record, the volunteer mentors usually check pupils' answers before they press the confirm button. When the pupils give a wrong answer, volunteer mentors would stop them from pressing the confirm button, and then ask the pupils questions constantly

to clarify their mathematical concepts until they understand. Therefore, the accuracy rate is higher than SDL.

However, high-achieving students usually complete their answers directly and send their answers without waiting for the volunteer mentors to confirm. In contrast, pupils who have little confidence in mathematics usually wait for the volunteer mentors to check their answers.

3.3 The Development of Pupils' Self-directed Learning

This study used the nonparametric Wilcoxon Signed Rank Test for comparing pupils' math tasks between the first and second semester in the quantity of pupils' SDL by using the learning tasks on the Math Island pupils did on their own. The mean rank in the pupils' task amount in the second semester (M=29.50, SD=27.02) is higher than in the first semester (M=.90, SD=2.23). The Z value is -2.668 and the significance level is at a .008 significance level indicating a statistically significant SDL increased from the first to the second semester.

3.4 Pupils' Mathematics Learning Ability

Wilcoxon Signed Rank Test for comparing pupils' pre-test and post-test scores, the mean rank in the pupils' scores on the post-test (M=103.4, SD=18.37) is higher than the scores of the pre-test (M=76.6, SD=21.83). The Z value is -2.805 and the significance level is below .01. In other words, there was a significant difference between pupils' pre-test scores and post-test scores. In this study, those pupils who participated in the distance learning and were taught by volunteer mentors had a higher level of mathematics achievement from the post-test than the pre-test at a .005 significance level. After the given 13-week distance learning period, the post-test scores of the pupils in comparison with the pretest score increase significantly. Therefore, using the gamified mathematics platform for distance learning can improve the pupils' mathematics learning ability.

This study also uses Pearson Correction to examine the relationship between pupils' math tasks and their post-test mathematics scores. There was a strong and positive correlation between the completion amount of the third-grade math tasks (N=102) and post-test mathematics scores (M=103.40) with the values of r= 0.747, n= 10, and p= .013. This result indicates that the highly math-tasks completion was positively correlated with the post-test math performance. Therefore, the pupils doing more math tasks may enhance their mathematics learning performance.

4 Discussion

The purpose of this research is to foster pupils' SDL and mathematics abilities. Although the math tasks were assigned by the class teachers, the speed of learning is mainly determined by the pupils. However, when pupils encounter difficulties during learning, mentors may stop pupils from going to the next learning tasks and guide them in different ways. Sometimes mentors who lack teaching experience may result in pupils' ineffective distance learning and delay their learning speeds. Pupils may raise their correct rate but do fewer learning tasks.

The pupils who have better learning abilities may do more tasks. However, some high-achieving students don't need to do so many practice questions, they still have high math scores, and some low-achieving pupils with good mentors' guidance can do a lot of math tasks and develop their SDL.

Finally, although this study uses a game platform to support pupils' learning, but pupils did not engage in playing the game. This study observes that only a small number of pupils were affected by the mechanism of games and thus do a lot of math tasks. But they gradually reduce game participation over time and pay more attention to learning mathematics, which may relate to the purpose of classroom learning and teacher expectations. However, it requires further exploration and analysis.

5 Conclusion

To foster pupils' self-directed learning competencies, this study applied the mathematical the pupils were asked to do distance learning. This study examines pupils' learning characteristics, how the

volunteer mentors influence the pupils' learning, and whether pupils develop self-directed learning with the integration of distance learning through applying a gamified mathematical platform and improving their mathematical ability. The results showed that the pupils' learning characteristics about their learning variety such as math task completeness and game engagement, and were influenced by their classmates. Moreover, the volunteer mentors' teaching method may influence pupils' learning speed and correct rate than what pupils could do in self-directed learning independently. Furthermore, the pupils under distance learning gradually developed their self-directed learning ability in the second semester, and their mathematics learning ability in post-test also improved significantly and had a positive correlation with the practice amount of math tasks. Future research should focus on how the volunteer mentors teach the pupils and how to collaborate with the class teacher and change their teaching behaviors as they apply "Math-Island" to help pupils' distance learning.

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