

Article

Implementation of Mobile Learning in Mathematics Instruction for Elementary Second Graders

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Abstract: In this study, a mobile learning system (MLS) was developed and adopted to facilitate elementary second-grade students to learn mathematics. A quasi-experimental design was adopted. There were two learning models, including the typical instruction group (TI group) and MLS group. The learning content is the topic of multiplication. A total of 93 s-grade students from four classes in a public elementary school in Northern Taiwan participated in this research. Participants were randomly divided into the MLS group (47 participants: 22 boys and 25 girls) and the TI group (46 participants: 26 boys and 20 girls). Participants in the MLS group received mathematics instruction in the MLS, whereas those in the TI group received direct instruction in typical classrooms. All students took the pretest and posttest of mathematics learning achievement test and mathematics learning interest scale assess their improvement of learning achievement and learning interest after the learning activities. The findings revealed that students in the MLS group had significantly better improvement in their mathematics learning interest and mathematics learning achievement than those in the TI group. In addition, students in the MLS group had significantly better performance in answering items of comprehension and application levels in the mathematics learning achievement test.



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Keywords: mathematics instruction; mathematics learning interest; mobile learning; multiplication; elementary school students

1. Introduction

1.1. Mathematics Multiplication Teaching

Teaching mathematics involves cultivating students' logical thinking and their use of concepts to solve problems in daily life. In elementary mathematics courses, addition, subtraction, multiplication, and division are basic arithmetic operations that also function as the foundation of mathematics. Acquiring arithmetic operations and knowing how to use them can improve students' mathematical abilities. According to the mathematics course standards proposed by the National Council of Teachers of Mathematics (NCTM), basic understanding of multiplication is conducive to the development of higher-level mathematics abilities and achievements. Conceptual development should precede exceptional calculation ability to realise meaningful learning among students [1]. Some mathematics education research pointed out that students who learned procedure or arithmetic skills first did worse than those who learned concepts first, and this sometimes hindered their learning of multiplicative reasoning [2,3]. Understanding multiplication is essential and affects the subsequent learning success of students [4]. Multiplication is derived from addition. Teaching multiplication concepts normally begins in second grade in an elementary school. Multiplication not only represents the fundamental arithmetic operations of number and quantity, but it also plays a crucial role in the subsequent learning of graphic and geometry, probability and statistics, and algebra. In terms of teaching methods for mathematical multiplication, teachers should take advantage of signs, verbal guidance, and visual aids to help students to navigate the relationships and connections between

concepts [5]. Diverse problems should be provided to stimulate students' thoughts and enable them to discover the real-life applications of multiplication [6]. Teachers should help students practice operations, and they should use multiple representations such as graphics, language, signs, and teaching tools to help students quickly understand abstract mathematical concepts, use abstract mathematical concepts to think and solve problems, and find various solutions to mathematical problems [7,8]. Teachers should draw from students' previous experience to build scaffolds that help students transition from thinking in terms of concrete operations to abstract concepts through specific methods that facilitate exploration and discovery of problem-solving strategies and the regularity of mathematics. Consequently, students can swiftly transition from addition to multiplication concepts [9]. Teachers should design homework assignments and provide opportunities for students to apply mathematics in daily life so that students will discuss mathematics with each other [7,10]. When students realise that multiplication can be used to solve certain problems faster than addition, they may be more motivated to learn multiplication concepts. Therefore, students can use multiplication instead of addition to solve problems and acquire new knowledge, thereby increasing their learning effectiveness and interest.

1.2. Mathematics Learning Interest

Studies have found that students' interest in learning significantly and positively affected their learning achievement [11,12]. NCTM [7] proposed in *Professional Standards for Teaching Mathematics* that teaching content must arouse students' learning interest and provide them with opportunities to learn and apply mathematics. In addition, teachers must help students use tools and connect new and previously learned concepts. In 2000, NCTM published the *Principles and Standards for School Mathematics*, which indicated that students should learn mathematics through various comprehension methods and be able to acquire new knowledge through prior experience. That is, elementary students must learn addition before learning multiplication concepts. Students' multiplication cognition abilities, previous experience, and prior knowledge must be considered to design multiplication courses suitable for student learning. The learning content of teaching materials and activities must also be able to trigger students' interest in learning [7].

Interest and learning are closely entangled [13], and different situations may directly or indirectly affect learning and participation attitudes [14]. When students are interested in certain tasks or activities, they spend more time on them and exert more effort to form effective learning behaviours such as generating questions and seeking answers out of curiosity and developing self-regulation, in-depth strategies, and problem-solving abilities [15–18]. Students with greater interest in learning have greater learning achievements [19]. That is, interest in learning positively affects students' learning achievements as well as their persistence and their eagerness to learn [20,21]. Moreover, Hidi and Renninger [22] and Renninger and Hidi [23] proposed the Four-Phase Model of Interest Development and suggested that interest consists of cognitive and affective components that interact with each other. Intervention of the external environment triggers situational interest and further affects cognition in individuals, the development of individual interest, and individual attitudes and learning effectiveness in the learning of tasks [22]. In terms of educational research, there are two types of interest, namely situational and individual. Situational interest refers to the focus and emotional interaction driven by stimuli or intervention in context [24,25], whereas individual interest refers to an individual's long-term persistent inclination to participate in certain activities repeatedly and the psychological status triggered by such inclinations [26–28]. Hidi and Renninger [22] further indicated that the interaction of the positive effects resulting from situational and individual interest positively affect cognitive performance.

Hidi and Renninger [22] and Renninger and Hidi [23,29] proposed teaching strategies to improve learning interest in accordance with different interest development phases and teaching sites. To trigger and maintain situational interest, teachers can use group activities, puzzles, computer-based multimedia, project-oriented learning, and expert

strategies in their teaching practices. To develop individual interest, teachers must focus generating individual interest and external support from experts and peers, which can reinforce learning comprehension. Situational interest is fundamental to overall interest development [22,23,29]. In terms of mathematics instruction, situated learning is also a crucial approach for creating meaningful learning environments [30,31]. Therefore, the present study adopted the viewpoint of situational interest and situated learning to develop a learning environment to help elementary school students learn multiplication concepts. The multiplication learning activities designed in this research is shown in Section 2.2.1.

1.3. Mobile Learning

According to United Nations Educational, Scientific, and Cultural Organization [32], mobile technology has rapidly changed the learning patterns of human beings. Mobile technology promotes mobile learning, which enables real-time feedback between teachers and students to facilitate favourable learning progress. In addition, mobile technology supports learning in various situations. Advances in mobile technology have helped drive ubiquitous learning and promote situated learning [32]. Mobile technology supports traditional lecture-based teaching and is convenient for collecting and sharing information and developing innovative teaching methods [33,34]. In addition, Sung et al. [35] suggested that mobile learning substantially affects the learning performance of preschool and elementary school students. Specifically, moderate effects were observed among junior high and senior high students. In addition, studies have reported that the application of mobile learning in mathematics instruction has positively affected students' learning achievement, motivation, attitudes, and cognitive skills [33,36].

Although mobile learning has numerous advantages, learners easily become disoriented in mobile learning environments [37]. Wang and Yang [37] indicated that mobile learning can help learners to learn in real-life situations and connect learning information between physical and digital environments. Mobile learning increases the flexibility and extensiveness of teaching and learning. However, these advantages are associated with certain problems. In contrast to the conventional integration of information technology in teaching and learning, mobile learning requires frequent switching between real and digital environments, which may aggravate the aforementioned disorientation experienced in mobile learning. Moreover, the presentation of multiple teaching materials causes the split attention effect, in which students must retain partial messages, look for relevant messages, and generate excessive external cognitive loads. Therefore, relevant teaching materials must be adequately integrated both spatially and temporally [38].

Therefore, a teaching model or strategy must be developed to solve the negative effects of mobile learning [39], namely disorientation [37], split attention [37,40], and input difficulty [41]. Quick response (QR) code technology and image capture functions of smart mobile devices can solve these problems by reducing the difficulty of using existing learning platforms, which often require children log in using personalised credentials. Avoiding this hassle can help children focus on learning content. A QR code is a two-dimensional barcode in a pattern composed of black and white squares and can display more than 1000 characters. To request messages hidden by QR codes, users must have a QR code reader application on their smart mobile devices (e.g., smart phones or tablet computers) with cameras. After users open the application and use the camera to scan the QR code, the application decodes the message and generates a uniform resource locator (URL). Users can directly access the decoded URL through a browser. That is, users can simply use the internal camera in their smart mobile device to scan a QR code and access and browse information [42]. Teachers can use a QR code to construct a teaching sequence by printing it on a worksheet for easy access to the courses. This process provides students with scaffolding instruction of specific content, promotes effective access to learning resources and therefore improve learning outcomes [42,43]. In addition, this approach helps students focus on the provided learning content [41,44,45]. In addition, the internal camera can help

students present their ideas in the online forum using images. These advantages benefit students and enable them overcome their limited technological skills [46].

Compared with the traditional classroom in which mathematics teaching activities mainly focus on the teacher's narration, digital and mobile technology help teachers introduce diverse situations to students, enabling them to employ multiple representation methods to perform concrete operations or think abstractly, which elicits and maintains students' learning interest. Through image capture functions and QR code technology, teachers can provide specific teaching instructions and build learning scaffolds for students. Students can use cameras on smart mobile devices to scan QR codes overcome the difficulties of entering text by remotely accessing paper-based text and other digital materials. The image capture functions of smart mobile devices can help students upload and post their ideas using images, which are conducive to peer discussion. Accordingly, this study developed a mobile learning environment, the Mobile Learning System (MLS), to facilitate mathematics instruction. The MLS was used to design a multiplication learning course suitable for students' cognitive abilities. During the course, diverse mathematics problems were provided. Smart mobile devices with scanning and image capture functions were used to develop a step-based teaching process. Diverse presentation methods including graphics, videos, and signs were implemented to help students grasp multiplication concepts through mobile learning. In addition, students participated in online tests to receive immediate feedback. Please Section 2.2.1 for details.

Based on the above, two teaching models were designed in this study. One was the typical instruction model (TI model), mainly applied by teachers in the classroom teaching with the use of the blackboard and the textbook; and the other teaching model referred to teachers using MLS to teach. Overall, two research questions were addressed:

1. Compare with the TI model, what is the effectiveness of the MLS in facilitating elementary second-grade students' mathematics learning interest?
2. Compare with the TI model, what is the effectiveness of the MLS in facilitating elementary second-grade students' mathematics learning achievement?

2. Materials and Methods

2.1. Participants

The participants were 93 second-grade students from four classes in a public elementary school in Northern Taiwan; 48 were boys and 45 were girls. The students were divided and placed in the MLS group (47 participants, 22 boys and 25 girls) and the TI group (46 participants, 26 boys and 20 girls). Participants in the MLS group received mathematics instruction in the MLS, whereas those in the TI group received TI. Details are provided in Section 2.3.

2.2. Instruments

2.2.1. Learning Contents and Activities

The learning contents comprised four topics about multiplication: understanding multiplication; solving multiplication problems involving 2, 4, 5, and 8 ($\text{multiplier} \leq 9$); becoming familiar with multiplication problems involving 2, 4, 5, and 8; and developing and solving multiplication problems in given situations.

The procedure of learning activities is as follows: Students were first required to count using circle selection when asked by the life situation questions. Then, they presented their own recording methods, explaining and compared different records with peers. After repeated multiple questions on the daily life questions, students were familiar with the concept of unit quantity. Next, the previous recording method was converted into the multiplication sentence, aiming to make students understand the mathematical meaning of each part of the multiplication sentence as well as understand their learning situation. Finally, students were asked to design a situation question that conformed to the multiplication sentence and made an illustration. The learning activities of MLS group and TI group are shown in Table 1.

Table 1. A comparison of the procedure of learning activities in MLS group and TI group.

Task	Explanation	MLS Group	TI Group
1	Please look at the picture and answer the question: How many ears does a rabbit have? How many rabbits are there in the picture? How many ears of rabbits are there in the picture? Please record how you calculated them.	Students scan the QR code to read the MLS learning content and see the graphics and questions. Students record their answers and problem-solving procedure on paper and take photos and upload them to the online forum in the MLS.	Students are required to read the textbook and listen to the teacher's instruction written on the blackboard. Students give oral answers and write down the problem-solving procedure in the margins of the textbook.
2	Make an explanation on how you calculate all the ears of rabbits.	Make an introduction of the problem-solving procedure, and then upload it to the online forum by taking photos or video recording with verbal explanation.	Have some students introduce their problem-solving procedure orally or using the blackboard.
3	Repeat Task 1–2, change the question into: How many feet does a chicken have? How many chickens are there in the picture? How many chicken feet are there in the picture?	The same as Task 1–2.	The same as Task 1–2.
4	Compare the similarities and differences in the problem-solving procedure between Task 1–2 and Task 3.	Respond to the similarities and differences between your peers' problem-solving procedure and yours in the online forum.	Have some students orally or use the blackboard to explain the similarities and differences in the problem-solving procedure between theirs and yours.
5	Convert your own problem-solving record into the multiplication sentence.	Students work out multiplication sentence.	Students work out multiplication sentence.
6	Learn the mathematical significance of each parts of the multiplication sentence.	Students enter the MLS to read the graphic instructions and learning videos.	Students are required to read the textbook and listen to teacher's narration and the blackboard description.
7	Test and correction	Students take an online test in the MLS. They can see the explanation of each question, knowing whether their answers are correct or not after submitting their answers.	Students take the paper-and-pencil test and then the teacher make corrections and explanations for the whole class in the classroom.
8	Draw up the multiplication questions	Students draw up the questions using whiteboard or in a paper-and-pencil format and take photos for them. Students then upload these pictures to the online forum to discuss them with their peers in the MLS.	Students draw up the questions in a paper-and-pencil format, and some of the students present their questions orally or using the blackboard.

2.2.2. Mathematics Learning Achievement Test

This study administered the pretest and posttest of the mathematics learning achievement test to determine differences in student learning effectiveness between the MLS and TI groups after they were subjected to the respective teaching models. The mathematics learning achievement test comprises 23 items corresponding to the remember level and the comprehension and application levels of Bloom's taxonomy [47]. A two-way chart is presented in Table 2. All items on the mathematics learning achievement test were reviewed by three elementary school mathematics education and assessment experts, who provided recommendations for revision to ensure the suitability of the item distribution

and descriptions. The average difficulty of the items [48] was 0.68. The KR 20 [49] of the achievement test was 0.84.

Table 2. Two-way chart of the mathematics learning achievement test.

Learning Contents	Remember ¹	Comprehension and Application ¹	Total ²
Understanding, solving and becoming familiar with multiplication problems	3	8	11
Developing and solving multiplication problems in given situations	3	9	12
Total	6	17	23

Note: ¹ Cognitive process dimensions of Bloom's taxonomy. ² Number of items.

2.2.3. Mathematics Learning Interest Scale

The mathematics learning interest scale was used to evaluate the pretest and posttest results before and after the learning activities, respectively, to determine the difference in the improvement of mathematics learning interest of students in the MLS and TI groups. Regarding the validity, the mathematics learning interest scale was developed based on the Gable–Roberts Attitude toward School Subjects Instrument [50] and the Four-Phase Model of Interest Development proposed by Renninger and Hidi [23,29]. In total, 18 items were developed and rated using a 4-point Likert scale with 1, 2, 3, and 4 indicating ‘strongly disagree,’ ‘disagree,’ ‘agree,’ and ‘strongly agree,’ respectively. Higher scores indicated higher mathematics interest. In addition, all items were revised by elementary mathematics education and assessment experts. The wording was adjusted to a level comprehensible by second graders, who read the items in advance to ensure the suitability of the wording. Regarding reliability [51], the Cronbach's α value of the mathematics learning interest scale was 0.955.

2.2.4. Mobile Learning System (MLS)

Based on Hidi and Renninger [22], Renninger and Hidi [23,29], and UNESCO [32], smart mobile devices were adopted to develop mobile learning environments in support of situated learning to trigger student learning interest and promote learning achievement in mathematics. The design of MLS was based on the Four-Phase Model of Interest Development proposed by Hidi and Renninger [22] and Renninger and Hidi [23,29] as well as the teaching strategies recommended for each phase of interest development. For example, in the situational interest phase, group activities, puzzles, computer-based multimedia, topic-oriented learning, and expert opinions were incorporated. In the individual interest phase, generation of individual interest and external support was further emphasised. Strategies recommended by previous studies were adopted to help students receive encouragement from others during difficult situations to ensure they completed the tasks. In addition, this study incorporated suggestions from the NCTM [7] to help students learn mathematics in realistic scenarios and through different representations. Suggestions by Wickett [6] were also considered to facilitate students' learning through diverse mathematics problems. Therefore, the MLS was developed to integrate smart mobile devices with QR code technology to develop an appropriate situated learning environment. Functions of the MLS are introduced subsequently:

Students can use smart mobile devices to scan QR codes on worksheets (Figure 1) provided by teachers through the MLS and learn mathematics by remotely accessing digital learning content (Figure 2), online tests (Figure 3), and discussion forums (Figure 4). Such a design provides a scaffold to help teachers establish instructional procedures and learning resources to help students overcome the difficulties of entering text [41]. With the MLS, students can easily access paper-based and digital materials remotely to reduce the

negative effects of split attention and disorientation [37,40]. Through image capture and multimedia presentation functions, teachers used the MLS to develop various multimedia learning content. The MLS directly provides teachers and students with image capture, voice recording, and video recording functions that help teachers develop diverse situated learning content, which provides students with opportunities to experience multiple representations [5,7,8,22,23,29,32]. The discussion forum provided by the MLS enables teachers and students to discuss and interact. Students can enter text to express their thoughts and use the image capture or video recording functions on smart mobile devices to express their ideas or respond to other classmates' ideas. The image capture and video recording functions prompt students who are unfamiliar with keyboard use or text entry to participate in discussion, thereby promoting learning effectiveness [22,23,46] (Figure 4).



Figure 1. QR Code printed on a worksheet for students to scan and read the digital content.

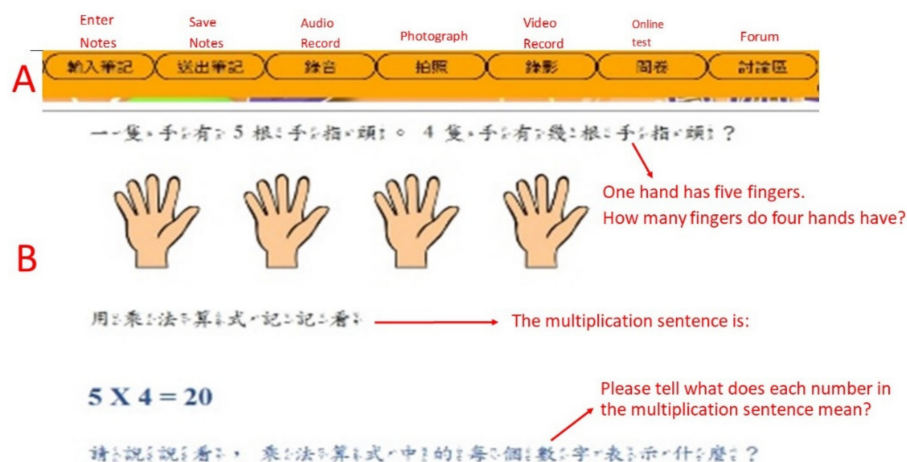


Figure 2. Student is reading the digital content of the MLS. (A) Function bar of MLS. (B) The learning materials are presented here.

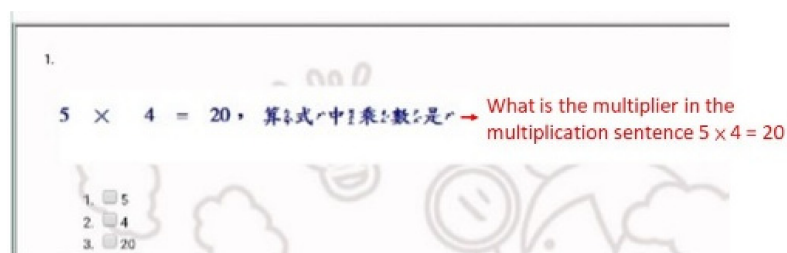


Figure 3. Student is taking an online test in the MLS.

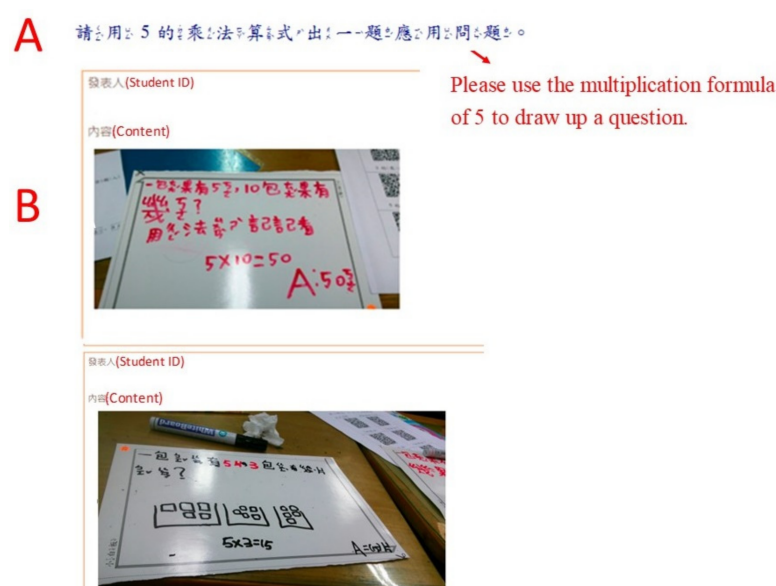


Figure 4. Students upload photos to participate in online discussion in the MLS. (A) The discussion topics in the online forum. (B) Students took photos of what they had written on the whiteboard and uploaded them to the online forum to participate in the discussion.

2.3. Research Design and Procedure

This study employed a quasi-experimental design and divided the four participating classes, with the class as the unit, into the MLS and TI groups (Table 1). The MLS group was subject to mobile learning in typical classrooms, where teachers used the MLS to administer learning activities. It included multiple representations and constructed learning situations administered through text, graphics, videos, and other multimedia. The MLS can automatically generate QR codes for each unit of learning content. The teacher prints the QR codes on worksheets, and the students scan the QR codes using the MLS to access the teaching modules and related digital content. Moreover, the students entering the online test zone in the MLS can perform problem-solving exercises and receive immediate feedback. The students can also submit text, images, or videos to the online forum to participate in online discussion or draw up multiplication problems. During discussion, the students expressed their thoughts and responded to other classmates' posts. The teacher did not provide additional instruction after such discussions.

The TI group was subject to teachers' direct instruction in typical classrooms. The learning contents were similar to that of MLS group (Table 1). The teachers narrated textbook content or wrote the content on the blackboard. During the teaching process, the students participated in paper-based tests. The teacher would then review the tests and provide the answers. The teachers also asked questions related to multiplication so that the students could openly express their ideas, participate in discussion, or propose their own problems about learning the concepts of multiplication. The main difference between the MLS and TI groups concerned the implementation of learning activities. For the TI group, the teachers adopted typical instruction models and applied verbal or written methods to facilitate mathematics learning, which involved administering paper-based tests and reviewing the test items. In the MLS group, during mathematics courses, students accessed learning content with QR codes to learn about multiplication concepts and complete online tests. The difference between the two groups in terms of peer interaction was that the students in the TI group openly expressed their thoughts during class, discussed problems related to multiplication, and proposed their problems about multiplication; by contrast, the students in the MLS group submitted text, images, or videos to the discussion forum to participate in online discussion.

The research procedure was conducted as follows: Before the learning activities, the MLS group used smart mobile devices to practice using the MLS. Subsequently, the

students in both the MLS and TI groups completed pretests based on the mathematics learning achievement test and the mathematics learning interest scale for understanding their entry behaviour. For both groups, learning activities were performed using the MLS and through TI, respectively, for eight 40-min sessions. After the learning activities, both groups completed posttests based on the mathematics learning achievement test and mathematics learning interest scale for determination of differences in their mathematics learning achievement and mathematics learning interest after being subjected to the two respective teaching models.

2.4. Data Collection and Data Analysis

Quantitative data related to the pretests and posttests based on the mathematics learning achievement test and the mathematics learning interest scale were collected. First, IBM SPSSTM 20 was used to perform an independent samples *t* test for analysis of the differences in entry behaviours between the two groups in terms of the results on the pretests of mathematics learning achievement test and mathematics learning interest scale. In addition, a one-way analysis of covariance (ANCOVA) was performed with the pretest scores of mathematics learning achievement test and mathematics learning interest scale as the covariates and the posttest scores of mathematics learning achievement test and mathematics learning interest scale as the dependent variables. Different teaching models were used as the fixed factor (two levels) to determine the difference in the performance of mathematics learning achievement and mathematics learning interest between the MLS (experimental) and TI (control) groups. Moreover, a one-way ANCOVA of the pretest and posttest results on the mathematics learning achievement test for both groups was conducted to determine the difference in student test performance in terms of the items of different cognitive process dimensions of Bloom's taxonomy.

3. Results

3.1. Analysis of Students' Mathematics Learning Interest

The pretest scores of mathematics learning interest scale for both the MLS and TI groups were analysed using an independent samples *t* test to determine the difference in entry behaviour in terms of mathematics learning interest between both groups. The result revealed that there was no significant difference ($t = 0.842$, $p = 0.402$), indicating that the students in both the MLS and TI groups had similar mathematics learning interest before the study. The descriptive statistics of the pretest and posttest scores of mathematics learning interest scale for both groups are provided in Table 3.

Table 3. Descriptive statistics of the pretest and posttest scores of mathematics learning interest scale.

Group	Pre-Test		Post-Test		<i>t</i> Value	Cohen's <i>d</i>
	Mean	SD	Mean	SD		
MLS (<i>n</i> = 47)	62.30	14.475	65.60	12.095	1.678	0.247
TI (=46)	59.96	12.216	59.50	12.202	−0.330	−0.038

Note: MLS: MLS group; TI: typical instruction group.

As indicated in Table 3, neither the MLS nor the TI group scored significantly higher on the posttest than on the pretest (MLS group: $t = 1.678$, $p > 0.05$, Cohen's $d = 0.247$; TI group: $t = -0.330$, $p > 0.05$, Cohen's $d = -0.038$). In order to understand the effectiveness of the two different teaching models in facilitating students' mathematics learning interest, the ANCOVA was adopted. Before ANCOVA, the assumption of homogeneity of regression coefficients was tested ($F_{1,89} = 3.468$, $p > 0.05$). This result indicated that homogeneity assumption was not violated. ANCOVA was conducted subsequently, and the results are presented in Table 4.

Table 4. ANCOVA summary table of the pretest and posttest scores of mathematics learning interest scale.

Source	Level	Mean ^a (Std. Error)	F Value	η^2	Post Hoc
Pretest Group	MLS	64.977 (1.442)	47.978 **	0.348	MLS > TI
	TI	60.132 (1.457)	5.563 *	0.058	

Note: * $p < 0.05$; ** $p < 0.01$; MLS: MLS group; TI: typical instruction group; ^a covariates appearing in the model are evaluated at the following values: Pretest = 61.14.

As indicated in Table 4, the pretest scores of mathematics learning interest scale had a significant influence on the posttest scores of mathematics learning interest scale ($F_{1,90} = 47.978$, $p < 0.01$, $\eta^2 = 0.348$). Different teaching models (Group) also had a significant influence on the posttest scores ($F_{1,90} = 5.563$, $p < 0.05$, $\eta^2 = 0.058$). The results of a least significant difference (LSD) post hoc analysis revealed that the mathematics learning interest of students in the MLS group was significantly higher than that of the TI group.

3.2. Analysis of Students' Mathematics Learning Achievement

The pretest scores of mathematics learning achievement test for both the MLS and TI groups were analysed using an independent samples t test to determine the difference in entry behaviour in terms of mathematics learning achievement between both groups. The result revealed that there was no significant difference ($t = 0.891$, $p = 0.375$), indicating that the students in both the MLS and TI groups had similar mathematics learning achievement before the study. The descriptive statistics of the pretest and posttest scores of mathematics learning achievement test for both groups are presented in Table 5.

Table 5. Descriptive statistics of the pretest and posttest scores of mathematics learning achievement test.

Bloom's Taxonomy	Group	Pre-Test		Post-Test		t Value	Cohen's d
		Mean	SD	Mean	SD		
All	MLS (n = 47)	15.77	4.017	20.94	1.607	9.809 **	1.690
	TI (=46)	14.93	4.941	19.89	2.759	7.837 **	1.240
Remember level	MLS (n = 47)	3.85	1.444	5.60	0.742	7.845 **	1.524
	TI (=46)	3.93	1.692	5.39	1.022	6.168 **	1.045
Comprehension and application levels	MLS (n = 47)	11.94	2.940	15.34	1.273	8.670 **	1.501
	TI (=46)	11.00	3.724	14.50	1.997	7.000 **	1.167

Note: ** $p < 0.01$; MLS: MLS group; TI: typical instruction group.

As indicated in Table 5, both MLS and TI groups scored significantly higher on the posttest scores than on the pretest (MLS group: $t = 9.809$, $p < 0.01$, Cohen's $d = 1.690$; TI group: $t = 7.837$, $p < 0.01$, Cohen's $d = 1.240$). In order to understand the effectiveness of the two different teaching models in facilitating students' mathematics learning achievement, the ANCOVA was adopted. Before ANCOVA, the assumption of homogeneity of regression coefficients was tested ($F_{1,89} = 1.199$, $p > 0.05$). This result indicated that homogeneity assumption was not violated. ANCOVA was conducted subsequently, and the results are presented in Table 6.

Table 6. ANCOVA summary table of the pretest and posttest scores of mathematics learning achievement test.

	Source	Level	Mean ^a (Std. Error)	F Value	η^2	Post Hoc
All	Pretest _{all} Group	MLS	20.839(0.291)	26.103 **	0.225	MLS > TI
		TI	19.991(0.295)	4.168 *	0.044	
Remember level	Pretest _{rem} Group	MLS	5.603(0.125)	8.452 *	0.086	
		TI	5.348(0.126)	1.509	0.016	
Comprehension and application levels	Pretest _{com} Group	MLS	15.247(0.224)	18.498 **	0.170	MLS > TI
		TI	14.595(0.227)	4.142 *	0.044	

Note: * $p < 0.05$; ** $p < 0.01$; MLS: MLS group; TI: typical instruction group; Pretest_{all}: Pretest scores for all items; Pretest_{rem}: Pretest scores for the items of remember levels; Pretest_{com}: Pretest scores for the items of comprehension and application levels; ^a covariates appearing in the model are evaluated at the following values: Pretest_{all} = 15.35; Pretest_{rem} = 3.89; Pretest_{com} = 11.46.

As indicated in Table 6, the pretest scores of mathematics learning achievement test (Pretest_{all}) had a significant influence on the posttest scores of mathematics learning achievement test ($F_{1,90} = 26.103$, $p < 0.01$, $\eta^2 = 0.225$). Different teaching models (Group) also had a significant influence on the posttest scores ($F_{1,90} = 4.168$, $p < 0.05$, $\eta^2 = 0.044$). The results of an LSD post hoc analysis revealed that the mathematics learning achievement of students in the MLS group was significantly higher than that of the TI group.

The items in the mathematics learning achievement test were further divided into the remember level and the comprehension and application levels in accordance with the cognitive process dimensions of Bloom's taxonomy. The pretest and posttest performances for items of these levels for both groups were analysed (Table 5). As indicated in Table 5, the posttest scores of both groups significantly improved from the pretest scores for the items of remember level (MLS group: $t = 7.845$, $p < 0.01$, Cohen's $d = 1.524$; TI group: $t = 6.168$, $p < 0.01$, Cohen's $d = 1.045$). In addition, the posttest scores significantly improved from the pretest scores for the items of comprehension and application levels (MLS group: $t = 8.670$, $p < 0.01$, Cohen's $d = 1.501$; TI group: $t = 7.000$, $p < 0.01$, Cohen's $d = 1.167$). The ANCOVA was also adopted to do further analysis. Before ANCOVA, the assumption of homogeneity of regression coefficients was tested (Remember level: $F_{1,89} = 1.926$, $p > 0.05$; Comprehension and application levels: $F_{1,89} = 0.368$, $p > 0.05$). These results indicated that homogeneity assumption was not violated. The ANCOVA results are presented in Table 6.

Table 6 indicates that the pretest scores for the items of remember level (Pretest_{rem}) had a significant influence on the posttest scores ($F_{1,90} = 8.452$, $p < 0.05$, $\eta^2 = 0.086$). However, the different teaching models (Group) did not have a significant influence on the posttest scores ($F_{1,90} = 1.509$, $p > 0.05$, $\eta^2 = 0.016$). The pretest scores for the items of comprehension and application levels (Pretest_{com}) had a significant influence on the posttest scores ($F_{1,90} = 18.498$, $p < 0.01$, $\eta^2 = 0.170$). The different teaching models (Group) also had significant influence on posttest scores ($F_{1,90} = 4.142$, $p < 0.05$, $\eta^2 = 0.044$). The LSD post hoc analysis revealed that the performance of students in the MLS group was significantly greater than that of the TI group. That is, the MLS group significantly outperformed the TI group for the items of comprehension and application levels in the mathematics learning achievement test.

4. Discussion and Limitations

The MLS developed in this study was based on the statement of using a mobile learning model to support situated learning [32]. The suggestions on improving learning interest [21–23,29], learning achievement [5,7,8,19,23,29,32], negative effects of students' limited technology skill [41,42,46] and mobile technology [37,40] were also taken into consideration to design the interactive functions of the MLS, including QR codes, multimedia

presentations, online tests, and discussion forum functions. The MLS was used to help elementary second graders learn mathematics and increase their mathematics learning interest. Compared with the typical instruction, students in MLS group exhibited significantly greater mathematics learning interest and mathematics learning achievement. The results indicated that the designs in the MLS, including QR codes, multimedia presentations, online tests, and discussion forum, increased students' mathematics learning interest. A possible reason for this is that compared with TI, the MLS provides greater technology support to teachers, helping them develop multimedia-based teaching content in support of situated learning. The learning materials offered in the MLS group and the TI group are the similar, but they are performed differently. During the learning procedure, the blackboard, paper and pencil, information and communication technology are all artefacts, which facilitate mathematical signs learning [52]. Research findings suggested that teachers should adopt multiple representations as much as possible to illustrate the same mathematical concept in the teaching of mathematics [7–10]. That is, teachers need to use multiple artefacts illustrating the same mathematical concept. Students from TI group in this study were passively received the representation provided by the teacher rather than positively chose their preferred representation to learn. While in MLS, the teacher illustrated the same question in Task 1 using different artefacts, such as text, graphics and videos, and thus students could choose their preferred presentation to view the content for effective learning. In addition to increasing the types of presentations for students to choose, MLS has other functions designed to facilitate learning. In Tasks 2, 4, and 8, students from the MLS group uploaded their problem-solving procedure to the online forum by means of taking pictures or videos after they finished answering the questions. In the forum, students could see the problem-solving procedure of the whole class, and meanwhile they could also see their own ideas expression and replies to the peers' ideas. Compared with TI group students who could only see a few students responding and discussing their ideas in class, MLS group students had a higher participation rate and interactivity. In Task 7, MLS group students took online tests and received immediate feedbacks. They adjusted their learning according to the results of the online self-assessment and thus improved their learning achievement while maintaining their learning interest [22,23,29,32]; whereas the TI group students conducted a paper-and-pencil test followed by unified corrections and instructions which were not immediate feedbacks. Besides, the image capture and video recording functions mitigated the negative effects of limited technology skills. Through these functions, the students who were unfamiliar with entering text could participate in online discussion and obtain learning resources, thereby increasing their learning interest [22,23,29,41,46]. Moreover, the MLS mitigated the possible negative effects of mobile learning on students. For example, the MLS integrated the multimedia functions that students require for mathematics learning; students did not have to switch between software programs, thereby reducing incidences of distraction and disorientation during digital learning. The incorporation of QR codes and the image capture functions of smart mobile devices enabled suitable temporal and spatial integration between paper-based and digital materials, which mitigated the split attention effect, redundancy, and disorientation [37,40].

Compared with the TI group, the MLS group also exhibited greater performance for items of comprehension and application levels in the mathematics learning achievement. However, no significant difference was observed for items of the remember level. This finding corresponds to that of Bano et al. [33] and Fabian et al. [36], in which mobile learning was reported to improve students' mathematics learning achievement. The possible reasons for the significant difference between the two groups in terms of the performance for items of the comprehension and application levels was that the MLS provided various multimedia for teachers to perform multiple representation and enabled students to engage in concrete or abstract thinking exercises. This made the MLS group have significantly better performance than the TI group in the overall mathematics learning achievement, as well as higher levels of achievement on corresponding test items [5–9]. According to suggestions by Stein et al. [10] and the NCTM [7], teachers can improve

mathematics learning effectiveness by facilitating discussion among students through the provision of realistic scenarios for applying mathematics concepts to problem-solving. Students in both the MLS and TI groups were able to propose their problems. The difference was that the MLS group had discussions in the online forum, whereas the TI group had few opportunities for verbal or writing-based (blackboard) presentations because of time constraints. The TI group had to develop a presentation based on ideas recorded on paper before discussing it with their peers. By contrast, the MLS group recorded their thoughts by recording videos or taking pictures of their ideas recorded on paper and uploading them to the MLS as a presentation discussing it with their peers. The online forum of the MLS enabled the students to verbally present their ideas in an informal tone or upload their written ideas to facilitate discussion. The constraint of students' limited technology skills was mitigated, which provided the students with more opportunities to participate in discussions and increased the overall quality of discussions, thereby promoting mathematics learning achievement [22,23,29,46].

Nonetheless, the current study had several limitations. Mobile learning requires a stable wireless network. Students should be familiar with the basic functions of smart mobile devices and mobile learning before they start learning courses. Thus, wireless network stability and students' familiarity with mobile learning functions and designs affected the research results. Network connection quality and students' technological literacy and skills should be considered in future research on mobile learning and related teaching practices. In addition, mobile learning applications in mathematics instruction is new to students; therefore, a pronounced novelty effect may have influenced the research results [53,54]. Therefore, the research periods of future studies should be extended to include more learners from more schools and in different learning phases, and more course topics (for different subjects) should be incorporated to increase the inference of the research results in terms of mobile learning. Future studies should include in-depth interviews with students, employ open-ended questionnaires or other qualitative methods to determine differences in students' learning processes, or analyse the behavioural data or responses of students subjected to digital learning systems. Such qualitative data would complement quantitative data collected through scales and questionnaires, thereby elucidating the real effects of mobile learning on students' mathematics learning.

5. Conclusions

Smart mobile devices should be used to develop mobile learning environments for mathematics instruction. Multiple representation, online test, QR codes, image capture, video recording, and online forum should be effectively integrated. These functions helped teachers develop learning activities in support of situated learning. The multiple representation by means of applying information communication and technology to integrate multimedia such as text, graphics, and videos to teach mathematical concepts can facilitate students to learning more effectively. The online test provided opportunities for students to do self-assessment, and therefore students can monitor their own learning conditions and improve their learning achievements and learning interest. Moreover, QR codes can help students access diverse digital learning resources and experience multiple representations to facilitate learning. In addition, QR codes can also help teachers construct a teaching sequence to provide a scaffolding for students to do mobile learning. The image capture and video recording functions of mobile devices are valuable to elementary students in lower grades or learners unfamiliar with operating such devices. These functions enable students to take pictures of their written work and record their ideas with videos, which can be uploaded to the online forum for discussion, helping students to express their thoughts. Through online discussion, students can interact with teachers and peers; thus, the effects of students' limited technology skills can be minimised in mobile learning. Therefore, mobile learning can effectively improve mathematics learning interest and achievement in elementary students in lower grades.

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References

1. National Council of Teachers of Mathematics. Overview of Principles and Standards for School Mathematics: Standards for School Mathematics. Available online: <https://www.nctm.org/Standards-and-Positions/Principles-and-Standards/> (accessed on 17 June 2021).
2. Anthony, G.; Walshaw, M. Swaps and switches: Student's understanding of commutativity. In *Mathematics Education in the South Pacific (Proceedings of the 25th Annual Conference of the Mathematics Education Research Group of Australasia, Auckland, pp. 91–99)*; Barton, B., Irwin, K.C., Pfannkuch, M., Thomas, M.O., Eds.; MERGA: Sydney, Australia, 2002.
3. Pesek, D.; Kirshner, D. Interference of Instrumental Instruction in Subsequent Relational Learning. In *Lessons Learned from Research*; Sowder, J., Schappelle, B.R., Eds.; National Council of Teachers of Mathematics: Reston, VA, USA, 2000; pp. 101–107.
4. Vergnaud, G. Multiplicative conceptual field: What and Why? In *The Development of Multiplicative Reasoning in the Learning Mathematics*; Harel, G., Confrey, J., Eds.; State University of New York Press: New York, NY, USA, 1994; pp. 41–59. ISBN 978-0-7914-1764-5.
5. Staples, M. Supporting whole-class collaborative inquiry in a secondary mathematics classroom. *Cogn. Instr.* **2007**, *25*, 161–217. [\[CrossRef\]](#)
6. Wickett, M.S. Links to Literature: Amanda Bean and the Gator Girls: Writing and Solving Multiplication Stories. *Teach Child Math* **2000**, *6*, 282–303. [\[CrossRef\]](#)
7. National Council of Teachers of Mathematics. *Professional Standards for Teaching Mathematics*; National Council of Teachers of Mathematics: Reston, VA, USA, 1991.
8. Lesh, R.; Post, T.; Behr, M. Representations and translation among representation in mathematics learning and problem solving. In *Problem of Representation in Teaching and Learning of Mathematics*; Janvier, C., Ed.; Erlbaum: Hillsdale, NJ, USA, 1987; pp. 33–40. ISBN 9780805800135.
9. Mulligan, J.T.; Mitchelmore, M.C. Young children's intuitive models of multiplication and division. *Math. Educ. Res. J.* **1997**, *28*, 309–330. [\[CrossRef\]](#)
10. Stein, M.K.; Grover, B.W.; Henningsen, M. Building student capacity for mathematical thinking and reasoning: An analysis of mathematical tasks used in reform classrooms. *Am. Educ. Res. J.* **1996**, *33*, 455–488. [\[CrossRef\]](#)
11. Wilkins, J.L.M. Mathematics and science self-concept: An international investigation. *J. Exp. Educ.* **2004**, *72*, 331–346. [\[CrossRef\]](#)
12. Mullis, I.V.S.; Martin, M.O.; Foy, P.; Hooper, M. TIMSS 2015 International Results in Mathematics. Available online: <http://timssandpirls.bc.edu/timss2015/international-results/> (accessed on 17 June 2021).
13. Rotgans, J.I.; Schmidt, H.G. Situational interest and learning: Thirst for knowledge. *Learn Instr.* **2014**, *32*, 37–50. [\[CrossRef\]](#)
14. Flowerday, T.; Shell, D.F. Disentangling the effects of interest and choice on learning, engagement, and attitude. *Learn Individ Differ.* **2015**, *40*, 134–140. [\[CrossRef\]](#)
15. Lipstein, R.; Renninger, K.A. "Putting things into words": 12–15-year-old students' interest for writing. In *Motivation and Writing: Research and School Practice*; Boscolo, P., Hidi, S., Eds.; Kluwer Academic/Plenum: New York, NY, USA, 2006; pp. 113–140. ISBN 9781849508216.
16. Mitchell, M. Situational interest: Its multifaceted structure in the secondary school mathematics classroom. *J. Educ. Psychol.* **1993**, *85*, 424–436. [\[CrossRef\]](#)
17. Renninger, K.A.; Hidi, S. Student interest and achievement: Developmental issues raised by a case study. In *Development of Achievement Motivation*; Wigfield, A., Eccles, J.S., Eds.; Academic: New York, NY, USA, 2002; pp. 173–195. ISBN 9780127500539.

18. Renninger, K.A.; Shumar, W. Community building with and for teachers: The Math Forum as a resource for teacher professional development. In *Building Virtual Communities: Learning and Change in Cyberspace*; Renninger, K.A., Shumar, W., Eds.; Cambridge University Press: New York, NY, USA, 2002; pp. 60–95. ISBN 9780521780759.
19. Harackiewicz, J.M.; Durik, A.M.; Barron, K.E.; Linnenbrink-Garcia, L.; Tauer, J.M. The role of achievement goals in the development of interest: Reciprocal relations between achievement goals, interest, and performance. *J. Educ. Psychol.* **2008**, *100*, 105–122. [\[CrossRef\]](#)
20. Ainley, M.; Hidi, S.; Berndorff, D. Interest, learning, and the psychological processes that mediate their relationship. *J. Educ. Psychol.* **2002**, *94*, 545–561. [\[CrossRef\]](#)
21. Zhang, Y.; Tao, O.; Wu, Q.; Wang, Y. SIMPP analysis on learning interest of students. *Chin. J. Med. Educ. Res.* **2015**, *7*, 663–666. [\[CrossRef\]](#)
22. Hidi, S.; Renninger, K.A. The four-phase model of interest development. *Educ. Psychol.* **2006**, *41*, 111–127. [\[CrossRef\]](#)
23. Renninger, K.A.; Hidi, S. Revisiting the conceptualization, measurement, and generation of interest. *Educ. Psychol.* **2011**, *46*, 168–184. [\[CrossRef\]](#)
24. Hidi, S. Interest and its contribution as a mental resource for learning. *Rev. Educ. Res.* **1990**, *60*, 549–571. [\[CrossRef\]](#)
25. Hidi, S.; Baird, W. Interestingness—A neglected variable in discourse processing. *Cogn. Sci.* **1986**, *10*, 179–194. [\[CrossRef\]](#)
26. Krapp, A.; Fink, B. The development and function of interests during the critical transition from home to preschool. In *The Role of Interest in Learning and Development*; Renninger, K.A., Hidi, S., Krapp, A.A., Eds.; Lawrence Erlbaum Associates, Inc.: Hillsdale, NJ, USA, 1992; pp. 397–429. ISBN 978-0126190700.
27. Renninger, K.A. Individual interest and its implications for understanding intrinsic motivation. In *Intrinsic and Extrinsic Motivation: The Search for Optimal Motivation and Performance*; Sansone, C., Harackiewicz, J.M., Eds.; Academic: New York, NY, USA, 2000; pp. 375–407. ISBN 9780126190700.
28. Renninger, K.A.; Wozniak, R.H. Effect of interest on attention shift, recognition, and recall in young children. *Dev. Psychol.* **1985**, *21*, 624–632. [\[CrossRef\]](#)
29. Renninger, K.A.; Hidi, S. *The Power of Interest for Motivation and Engagement*; Routledge: New York, NY, USA, 2017; ISBN 9781315771045.
30. Lui, A.M.; Bonner, S.M. Preservice and inservice teachers' knowledge, beliefs, and instructional planning in primary school mathematics. *Teach. Teach. Educ.* **2016**, *56*, 1–13. [\[CrossRef\]](#)
31. Van Oers, B. From context to contextualizing. *Learn Instr.* **1998**, *8*, 473–488. [\[CrossRef\]](#)
32. United Nations Educational, Scientific and Cultural Organization (UNESCO). Policy Guidelines for Mobile Learning. Available online: <http://unesdoc.unesco.org/images/0021/002196/219641E.pdf> (accessed on 17 June 2021).
33. Bano, M.; Zowghi, D.; Kearney, M.; Schuck, S.; Aubusson, P. Mobile learning for science and mathematics school education: A systematic review of empirical evidence. *Comput. Educ.* **2018**, *121*, 30–58. [\[CrossRef\]](#)
34. Sharples, M.; Taylor, J.; Vavoula, G. Towards a theory of mobile learning. In *Proceedings of the mLearn*, Qwara, Malta, 28–30 June 2005; pp. 1–9.
35. Sung, Y.T.; Chang, K.E.; Liu, T.C. The effects of integrating mobile devices with teaching and learning on students' learning performance: A meta-analysis and research synthesis. *Comput. Educ.* **2016**, *94*, 252–275. [\[CrossRef\]](#)
36. Fabian, K.; Topping, K.J.; Barron, I.G. Mobile technology and mathematics: Effects on students' attitudes, engagement, and achievement. *J. Comput. Educ.* **2016**, *3*, 77–104. [\[CrossRef\]](#)
37. Wang, T.H.; Yang, K.T. Technology-enhanced science teaching and learning: Issues and trends. In *Science Education Research and Practice in Asia—Challenges and Opportunities*; Chiu, M.H., Ed.; Springer: Cham, The Netherlands, 2016; ISBN 978-981-10-9268-8.
38. Mayer, R.E. Cognitive theory of multimedia learning. In *The Cambridge Handbook of Multimedia Learning*; Mayer, R., Ed.; Cambridge University Press: New York, NY, USA, 2005; pp. 31–48. ISBN 978-0521838733.
39. Froberg, D.; Göth, C.; Schwabe, G. Mobile learning projects—a critical analysis of the state of the art. *J. Comput. Assist. Learn* **2009**, *25*, 307–331. [\[CrossRef\]](#)
40. Sweller, J. Implications of cognitive load theory for multimedia learning. In *Cambridge Handbook of Multimedia Learning*; Mayer, R.E., Ed.; Cambridge University Press: Cambridge, UK, 2005; pp. 19–30. ISBN 978-0521838733.
41. Ozcelik, E.; Acarturk, C. Reducing the spatial distance between printed and online information sources by means of mobile technology enhances learning: Using 2D barcodes. *Comput. Educ.* **2011**, *57*, 2077–2085. [\[CrossRef\]](#)
42. Suarez, A.; Specht, M.; Prinsen, F.; Kalz, M.; Ternier, S. A review of the types of mobile activities in mobile inquiry-based learning. *Comput. Educ.* **2018**, *118*, 38–55. [\[CrossRef\]](#)
43. Gao, Y.; Liu, T.C.; Paas, F. Effects of mode of target task selection on learning about plants in a mobile learning environment: Effortful manual selection versus effortless QR-code selection. *J. Educ. Psychol.* **2016**, *108*, 694–704. [\[CrossRef\]](#)
44. Chen, X.; Choi, J.H. Designing online collaborative location-aware platform for history learning. *J. Educ. Technol. Dev. Exch. (JETDE)* **2010**, *3*, 2. [\[CrossRef\]](#)
45. Leone, S.; Leo, T. The synergy of paper-based and digital material for ubiquitous foreign language learners. *Knowl. Manag. E-Learn.* **2011**, *3*, 319–341. [\[CrossRef\]](#)
46. Huang, H.W.; Wu, C.W.; Chen, N.S. The effectiveness of using procedural scaffoldings in a paper-plus-smartphone collaborative learning context. *Comput. Educ.* **2012**, *59*, 250–259. [\[CrossRef\]](#)

-
47. Anderson, W.; Krathwohl, D.R. *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Educational Objectives*; Longman: New York, NY, USA, 2001; ISBN 9780801319037.
 48. Gable, R.K.; Roberts, A.D. An instrument to measure attitude toward school subjects. *Educ. Psychol. Meas.* **1983**, *43*, 289–293. [[CrossRef](#)]
 49. Ahmanan, J.S.; Glock, M.D. *Evaluating Student Progress: Principles of Tests and Measurement*, 6th ed.; Allyn & Bacon: Boston, MA, USA, 1981; ISBN 978-0205065615.
 50. Kuder, G.; Richardson, M. The theory of the estimation of test reliability. *Psychometrika* **1937**, *2*, 151–160. [[CrossRef](#)]
 51. George, D.; Mallery, P. *SPSS for Windows Step by Step: A Simple Guide and Reference, 11.0 Update*, 4th ed.; Allyn & Bacon: Boston, MA, USA, 2002; ISBN 978-0205375523.
 52. Bussi, M.B.; Mariotti, M.A. Semiotic mediation in the mathematics classroom: Artifacts and signs after a Vygotskian perspective. In *Handbook of International Research in Mathematics Education*, 2nd ed.; English, L.D., Kirshner, D., Eds.; Routledge Taylor & Francis Group: New York, NY, USA, 2008; pp. 746–783. ISBN 9780805858761.
 53. Collis, B.A.; Knezek, G.A.; Lai, K.-W.; Miyashita, K.T.; Pelgrum, W.J.; Plomp, T. *Children and Computers in School*; Lawrence Erlbaum Associates: Mahwah, NJ, USA, 1996; ISBN 9780805820744.
 54. Krendl, A.K.; Brohier, M. Student responses to computers: A longitudinal study. *J. Educ. Comput. Res.* **1992**, *8*, 215–227. [[CrossRef](#)]