Effectiveness of Digital Note-Taking on Students' Performance in Declarative, Procedural and Conditional Knowledge Learning

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Abstract—Note-taking is an ever-present learning activity in students' daily lives, and an increasing number of mobile terminals have been integrated into curriculums. However, the effectiveness of the use of digital note-taking on mobile terminals on students' learning has not been deeply explored. The purpose of this study is to evaluate how digital note-taking using mobile terminals affects student performance, with particular regard to declarative, procedural and conditional knowledge learning. A quasi-experiment was conducted for three months among 72 first-year high school students from a computer science (CS) course. In the study, students in the experimental group (n = 40) recorded notes digitally, whereas the students in the control group (n = 32) used the conventional approach (i.e., recording handwritten notes). The results indicate that the students who recorded notes digitally scored significantly higher than those who recorded notes conventionally. The students who were designated as "excellent," and those who were designated as "low-performing," were most likely to benefit from this new method of note-taking.

Keywords—Digital Note-Taking, Mobile Terminal, Declarative Knowledge, Procedural Knowledge, Conditional Knowledge, Students' Performance

1 Introduction

Despite the fact that many secondary schools have embraced innovative teaching methods, such as flipped classrooms and mobile learning, there remain numerous secondary schools that continue to use traditional methods[1]. It is therefore not surprising that note-taking remains a significant component of classrooms' formal teaching and learning process in the 21st century[2]. Regardless of research of Bui that claims that computers can be used for note-taking, many students still use the pen-and-paper method. Current research supports the previous findings, confirming that when students take notes using a mobile terminal, such as a laptop or mobile phone, it provides a scaffolding for contextualized and individualized learning, and it results in shallow cognitive processes[3]. Therefore, it seems worthwhile to further explore how mobile terminals can be used for educational purposes.

The process of note-taking in the computer science (CS) class is associated with action words and phrases such as capturing, recalling[4], learning, remembering[5], paying attention, organizing, recording, and making understandable and legible notes[6]. Mobile terminals have transformed note-taking for students and teachers, from a conventional paper-and-pencil method, to a digital method referred to in this article as "digital note-taking". This article analyzes the effects of digital note-taking using mobile terminals on student performance, with particular regard to declarative, procedural and conditional knowledge learning. The study investigates the following research questions:

- Do students taking digital notes perform better than those using conventional methods, specifically in regard to declarative, procedural and conditional knowledge learning?
- Do the effects of digital note-taking vary significantly depending on the students' level of academic achievement?

2 Literature Review

2.1 The value of note-taking with mobile terminals

The educational importance of note-taking has been acknowledged and emphasized worldwide. For example, Anderson and Armbruster[7], Ward and Tatsukawa [8] and Kobayashi[9] discovered that students who take notes learn and remember information while they are taking the notes, and they are better able to retrieve that information later. This phenomenon was also outlined by Bui et al., who stated that an increase in note-taking leads to an increase in positive effects on student learning, as more information is being processed by the students. In 1925, Crawford[10] discovered what Boyle and Forchelli[11] eventually confirmed in a more recent study—if students record high-quality notes, their learning and comprehension of the material improve. Nonetheless, for many years researchers have continued to confront the question of how secondary students can best capture and recall the flow of information in traditional lectures[12]. A possible explanation for the benefits of note-taking is that students who take notes need to pay attention, organize the information, and then record it in an understandable manner before it is forgotten[13]. Students utilize different note-taking methods, and experience different educational settings. Boyle and Forchelli suggest that researchers need to investigate the effectiveness of note-taking in different content areas relevant to the students' lives, and the influence of technology on note-taking[14].

In the past decade, many researchers have advocated for the use of computers and electronic note-taking systems for recording and summarizing important concepts in students' classes[15]. Itamiya, Tagawa and Chiyokura developed a new type of recording system, which integrates blackboard-writing and lecture images in real time using a camera[16]. A follow-up study revealed that the review efficiency of students improved due to the integration of the blackboard-embedded video. In a related study, Bui compared pen-and-paper note-taking with note-taking on a computer[17]. The authors found that computers were better for transcribing notes than for organizing them. Furthermore, when students were tested immediately after taking notes, the students who transcribed the notes achieved better scores than those who first organized them. However, care needs to be taken when integrating digital note-takings; to engage the student's mind, note-taking needs to be cognitively challenging, with technology playing a supporting role[18], rather than a distracting role[19]. Vincent argues that reading and writing online are more practical in teaching environments than traditional methods[20].

2.2 Research of declarative, procedural and conditional knowledge

Anderson categorized knowledge into three levels: declarative, procedural and conditional knowledge[21]. These three types of knowledge mutually depend on each other. Declarative knowledge is defined as explicit knowledge that students can report and that they are consciously aware of. Smith and Ragan further proposed subtypes of declarative knowledge: labels and names, facts and lists, and organized discourses[22]. There are three prominent methods utilized for learning declarative knowledge: connecting new and already-existing knowledge, rearranging the newly acquired knowledge, and articulating the new knowledge to make it meaningful for the learner. According to Schunk, procedural knowledge includes concepts, rules, and algorithms[23]. These statements describe the relationship between two or more concepts. Conditional knowledge consists of if–then statements, which are also called condition–action statements. "If" statements indicate conditions, and "then" statements indicate actions. Smith and Ragan illustrate that conditional knowledge enables learners to anticipate consequences if any condition is changed and originates from problem-solving activities in which goals are separated into sub goals of the operator. To obtain conditional knowledge, learners must determine the concepts related to the situation in the first place, and then choose specific rules that apply to the situation.

Smith and Ragan also suggest that the rules of procedural knowledge include a series of steps that is initiated in response to particular categories in order to achieve specific targets. Haye and Torres-Sahli analyze the divergence and correlation between declarative and procedural knowledge, and interpret them as "knowing something and knowing how to do something"[24]. In related research, Finn et al. revealed the developmental dissociation between the maturation of procedural memory and the maturation of declarative memory[25]. Additionally, Lefevre et al. explored the development of conceptual and procedural knowledge as seen through kindergarten students' ability to count[26]. They found a difference between the patterns of change for procedural knowledge and conceptual knowledge, where counting speed and accuracy (procedural knowledge) gradually improved with each successive grade. Gnambs, Appel, and Kaspar demonstrate the effect of the color red on encoding and retrieving declarative knowledge[27]; boys performed more strongly when red was present, whereas girls who received a similar single color manipulation experienced impaired knowledge retrieval. According to Mayer's theory of multimedia learning[28], all three kinds of knowledge could benefit from multimedia learning. Furthermore, Fabio and

Antonietti hypothesize that hypermedia instruction could improve the understanding and retention of declarative, procedural and conditional knowledge, because multimedia exposure proves to be particularly beneficial when the goal is to learn the basic concepts of a larger structure[29].

3 Experimental Design

3.1 Participants

The 72 participants of this study were selected from two classes in a senior high school that were both learning programming in their CS courses. A quasi-experimental design was implemented; 40 students were assigned to the experimental group that required digital note-taking, and the other 32 students were assigned to the control group that required traditional handwritten note-taking. Students in the experimental and control groups were categorized into three different levels according to the pretest: excellent students (top 30%), mid-level students (middle 40%), and low-performing students (lowest 30%). The information technology classes were led by a researcher to assure the consistency of the teaching activities. After the course, students were asked to take a programming test.

3.2 Experimental materials

Declarative knowledge refers to the knowledge of facts, concepts, events, and objects[30], which, when applied to computer science, can reference the basic concepts, definitions and theorems of computer algorithms; it refers to knowing what, while procedural knowledge refers to knowing how [31], such as understanding specific problem-solving methods and processes of programming. Conditional knowledge refers to the capacity to know when and under what conditions this knowledge can be applied to solve certain problems, which is a more comprehensive type of knowledge than the other two types.

Based on the "High School Teaching Guide" and the "Information Technology Basic Workbook", the "Algorithm and its Implementation" unit was selected as the primary teaching material. To classify different goals in declarative, procedural and conditional knowledge, three senior high school information technology teachers, who have each been teaching for more than 15 years, outlined the desired knowledge outcomes for the "Algorithm and its Implementation" unit. Two experts in information technology assessed the accuracy of these specific knowledge outcomes, resulting in the final draft as seen in Table 1.

Table 1. The classification of specific knowledge.

Knowledge Module	Specific Knowledge
Declarative knowledge	1. The concept, characteristics, and common representation of the algorithm 2. The concept of the object and its attributes, class, method and events 3. The expression specification of the object name 4. The error code and basic types of data 5. The concept and type of constant, variable and array 6. The different types and priorities of operators 7. The loop structures, i.e., if, for next, do while 8. The basic concepts of the analytic and enumeration algorithm
Procedural knowledge	1. The application and attributes of basic components 2. The write, run, debug, and save basic programs 3. The common usage of various functions 4. The usage of sequential, selection and loop structures
Conditional knowledge	The appliance of the first two types of knowledge to solve algorithm problems under specific conditions.

3.3 Demonstration of digital note-taking using mobile terminals

The digital note-takings referenced in this study are a method of writing, recording, storing and sharing notes on mobile terminals; they are a new resource for classroom teaching. In a teaching environment equipped with mobile terminals, an electronic pen, or even a finger, can write notes on the mobile terminals (see Figure 1). In this experiment, "Wireless Mirroring + Explain Everything" was the note-taking program used during the class. MirrorOp series software was used to interconnect the device with the projector, and Explain Everything was used to record the notes in the mobile terminals.

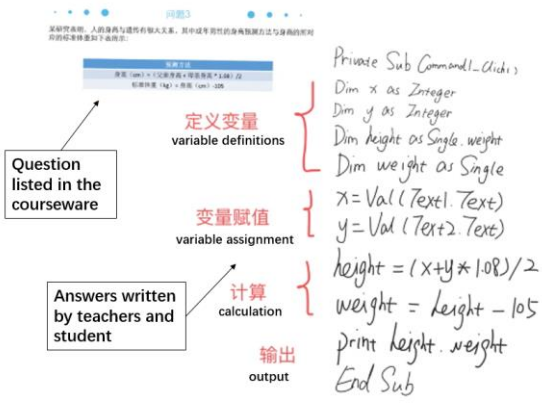

Fig. 1. Digital note-taking generated from a mobile terminal during class

3.4 Experimental procedure

The experiment was conducted over three months for one and half hours every week, with two classes per week, and each class lasting 45 minutes, as shown in Figure 2. In the first week, the students took a prior knowledge test, which tested students' prior knowledge about programming using 20 multiple-choice items and 15 fill-in-the-blank items, and with a highest possible score of 100. During the experiment, the researcher served as the instructor to ensure that the same teaching material was utilized in each mobile learning environment. The two groups of students were required to take notes during the class, and after each class, the teacher would store the notes from the mobile terminals and send them to the students in the experimental group.

To examine the effectiveness of the proposed method, all of the students were asked to complete a programming knowledge posttest. The posttest aimed to test the students' knowledge of programming in three categories, such as the meaning of the functions, explaining loop structures, or solving complex problems; it contained 10 multiple-choice items, 20 fill-in-the-blank items, 2 comprehensive question-and-answer items, and had a highest possible score of 100. The posttest was administered in the regular computer classroom. Both groups of students were allotted 20 minutes to read the notes before the test. The difference is that the experimental group received the digital note-takings as review material, while the control group used their daily handwritten notes. Additionally, students classified as "typical" were selected to participate in an interview following the analysis of the experiment.

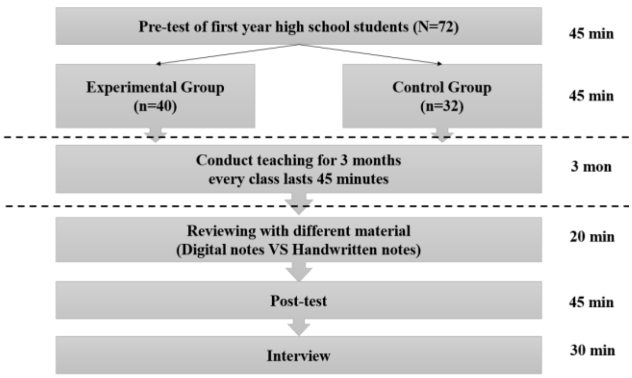

Fig. 2. Experimental procedure

4 Results

4.1 Analysis of students' pre-test programming knowledge

The programming knowledge pre-test examined the students' programming background knowledge before the experiment, while the posttest evaluated their programming knowledge after the experimental procedure. The programming knowledge posttest was designed in accordance with the teaching material of the unit and was assessed by two experienced teachers to ensure the accurate structuring of the three types of knowledge.

A programming knowledge pretest was conducted and revealed no significant difference between the students' scores in programming knowledge (p = .860). Additionally, there was no significant difference between the students based on their designated level of academic success, nor was there a significant difference between the two student groups (with p= .085, .441, .298 respectively). These results suggest that the two groups of students and the students of all three academic levels had equivalent programming knowledge before the study.

4.2 Performance of the experimental and control groups

An analysis of the students' post-test scores in programming knowledge was conducted after the experiment. As shown in Table 2, the experimental group that used digital note-takings outperformed the control group that used traditional handwritten notes. In addition, there was a significant difference between the scores of the two groups (t = -3.71, p < .001). Such results indicate that the digital note-takings improved learning outcomes for students' programming knowledge.

In regard to the three types of knowledge, there were significant differences between outcomes for the declarative knowledge module (t = -2.38, p = .020), the procedural knowledge module (t = -2.05, p = .044), and the conditional knowledge module (t = -2.71, p = .009). The results reveal that digital note-takings improved learning outcomes in all three categories of students' programming knowledge.

Table 2. Means, standard deviations, and independent t-test of post-test of the two groups.

Different Knowledge	Group	*n*	Mean	*SD*	*t*
Overall performance	Experimental Group	40	71.93	12.90	-3.71***
	Control Group	32	61.63	10.65	
Declarative knowledge	Experimental Group	40	38.48	8.99	-2.38*
	Control Group	32	33.38	9.05	
Procedural knowledge	Experimental Group	40	17.23	4.28	-2.05*
	Control Group	32	15.25	3.87	
Conditional knowledge	Experimental Group	40	15.58	3.65	-2.71**
	Control Group	32	13.00	4.43	

Note:
*p**<0.05
*p***<0.01
*p****< 0.001, *p*<0.05 indicates there is a significant difference between experimental and control groups.

4.3 Performance of students at different levels of academic achievement

As shown in Table 3, there was a significant difference between the posttests of the two groups of excellent students (p = .002). Specifically, there were significant differences in excellent students' declarative and procedural knowledge learning (p = .008

and .010), while there was no significant difference in excellent students' conditional knowledge learning (p = .161).

For mid-level students, there was no significant difference in overall performance (p = .186). Additionally, although the average scores of the experimental group were higher than those of the control group, there remained no significant difference in the mid-level student's acquisition of any of the three types of knowledge (p = .252, .689 and .290).

The analysis of low-performing students revealed no significant difference in knowledge acquisition following the study (p = .087). Specifically, no significant difference was found in these students' acquired declarative and procedural knowledge (p = .806 and .433). However, a significant difference was detected in the students' performance in conditional knowledge learning (p = .047).

The results reveal that the digital note-taking method improved learning outcomes for students' seeking to gain programming knowledge. However, the findings were inconsistent and differed significantly depending on the students' level of academic achievement.

Table 3. The result of performance of students in difference academic levels.

Different Knowledge	**Group**	***n***	**Mean**	***SD***	***p***
Overall performance					
Excellent students	Experimental Group	12	76.8	9.2	.002
	Control Group	10	60.0	12.9	
Mid-level students	Experimental Group	16	70.5	12.0	.186
	Control Group	12	63.9	13.6	
Low-performing students	Experimental Group	12	69.0	9.2	.087
	Control Group	10	60.5	13.0	
Declarative Knowledge					
Excellent students	Experimental Group	12	41.0	3.9	.008
	Control Group	10	31.0	11.1	
Mid-level students	Experimental Group	16	38.6	10.5	.252
	Control Group	12	34.2	9.2	
Low-performing students	Experimental Group	12	35.8	10.3	.806
	Control Group	10	34.8	6.7	
Procedural Knowledge					
Excellent students	Experimental Group	12	19.0	3.9	.010
	Control Group	10	14.8	3.6	
Mid-level students	Experimental Group	16	16.4	4.1	.689
	Control Group	12	15.8	4.8	
Low-performing students	Experimental Group	12	16.5	3.7	.433
	Control Group	10	15.1	4.6	
Conditional Knowledge					
Excellent students	Experimental Group	12	16.3	3.8	.161
	Control Group	10	14.2	2.6	
Mid-Level students	Experimental Group	16	15.4	3.1	.290
	Control Group	12	14.0	4.0	
Low-performing stu-dents	Experimental Group	12	15.1	4.4	.047
	Control Group	10	10.6	5.7	

Note. $p<0.05$ indicates there is a significant difference between experimental and control groups.

5 Conclusion and Discussion

In this study, a learning module was implemented for three months in a high school CS course to examine the effects of digital note-taking using mobile terminals on students' programming knowledge acquisition. After analyzing the experimental data, the researchers found that in regard to programming knowledge learning, the students writing digital note-takings outperformed those students' using conventional note-taking methods. This study also extended previous studies, which analyzed the overall impact of note-taking using mobile terminals[32] [33]. In regard to the three types of knowledge learning in the CS course, declarative knowledge refers largely to the conceptual content, procedural knowledge includes the operative content such as problem-solving steps and methods, and the prerequisite for learning conditional knowledge is to master the declarative and procedural knowledge. To achieve these outcomes, students need to fully understand the context and know what corresponding knowledge learning is required. The experimental analysis revealed that the students' learning outcomes in declarative, procedural and conditional knowledge of programming were significantly improved.

In regard to the effectiveness of digital note-taking for students in different academic achievement levels, there was an overall significant difference among excellent, mid-level and low-performing students. In declarative knowledge learning, there was a significant improvement for students designated as excellent, while for the other two groups of students, although there was an increase in average scores, the differences in test performance were not significant. Similarly, only excellent students appeared to benefit significantly in procedural knowledge learning. In regard to conditional knowledge learning, there was a significant difference in the performance outcomes of students designated as low-performing, while the differences in the performance of excellent and mid-level students were not significant.

Follow-up interviews were conducted to investigate the underlying reasons for these differences. The results of the interviews indicate that declarative knowledge learning in the classroom was often sourced directly from the text book, and to test this knowledge, students were expected to understand the meaning of concepts and provide explanations—information that could readily be acquired by students. In addition, the analysis of students in different academic achievement levels revealed that excellent and low-performing students benefitted the most from digital note-taking. However, there was no significant improvement for students in the mid-level group (although the general scores increased). Through student interviews, it became evident that the excellent students represented the dominant group with better learning capacities (i.e., better learning habits and memory capacity), which lead to superior knowledge acquisition during class[34]. On the other hand, low-performing students are those who normally lack the ability to gather effective materials, and they forget problem-solving processes more easily than others[35]; thus, the new learning materials could provide them with an opportunity for their improvement in conditional learning. For mid-level students, we recognized and thoroughly examined their challenge in confronting questions on the test, which were written differently than content in the class.

Overall, the study showed that digitized note-taking on mobile terminals could prove an effective approach to promote student learning in declarative, procedural and conditional knowledge, and improve the performance of students in different academic achievement levels (excellent students, mid-level students and low-performing students). Furthermore, with the development of technology, additional digital methods could be embraced to promote student learning.

However, there are still limitations to the study. Digital note-taking was only examined within CS class. To be widely-acknowledged, it must be tested and analyzed in various subjects. In addition, due to the constrictions of educational research, the experimental conditions were limited, and could be improved by conducting them at the same pace of the school. In conclusion, the rapid growth of digital learning methods, the increasing number of new technologies emerging every day, and the ever-changing teaching environments, all together illuminate the need for superior strategies to improve learning outcomes.

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