

# Effects of integrated information literacy on science learning and problem-solving among seventh-grade students

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## ABSTRACT

*How to educate students to be information literates has been an important issue today. The purpose of this research is to investigate the effects of integrating information literacy into science instruction on students' science learning and problem solving. In this quasi-experimental pre-post study, two 7th-grade classes from a public junior-high school in Taiwan were randomly assigned into an experimental group and a control group. The former received an inquiry-based science curriculum infused information literacy using the Big6 model, while the latter received traditional lecture-oriented instruction. The instructional unit in both groups was taught by the same teacher and lasted for about three weeks. Three tests were administered before and after the instruction to examine students' memorization of factual information, comprehension of scientific concepts, and problem solving skills. Results from the analyses of covariance showed that the experimental group significantly outperformed their counterparts on comprehension learning and problem solving, while not on the factual information acquisition. The findings from this study verify that integrating information literacy into regular curriculum using the Big6 model is applicable in school contexts. The instructional time used for the integrated instruction was beneficial to the learning of the subject content.*

**Keywords:** Information literacy; Inquiry learning; Big6 model; Problem-solving; Comprehension memory.

## INTRODUCTION

As the overwhelming flood of information bombards us, information literacy becomes crucial for successful survival in present knowledge society (AASL 2009). Therefore, how to effectively educate our children to be information literates has been the most important

issue today. A considerable amount of research indicated that the teaching of information literacy should be integrated into the regular curriculum using inquiry-based learning (Chen 2012; Chu, Tse and Chow 2011; Eisenberg 2007; Kuhlthau, Maniotes and Caspari 2007). However, the results are not consistent with related studies which investigate the effects of inquiry-based learning on students' deep thinking (e.g. comprehension) and factual information acquisition (e.g. memory) (Chang and Mao 1998; Chen 2011; Chu, Tse and Chow 2011; Houle and Barnett 2008; Taraban et al.; Wilson et al. 2010).

The Big6 model is used as the inquiry framework for this study to examine the effectiveness of an inquiry-based approach in guiding students through problem solving and improving memorization and comprehension of subject matters. The Big6 model, created by Eisenberg and Berkowitz, is selected primarily because it has been used by thousands of K-12 schools worldwide, and it provides a user-friendly approach to what are often complex tasks (Eisenberg et al. 2000; Eisenberg, Lowe and Spitzer 2004; Thomas, Crow and Franklin 2011). However, there is only a limited number of studies that look into what constitutes an effective Big6 model, and few empirical studies have investigated the Big6 model's effects on problem solving and subject content learning (Chen 2010; Lowery 2005; Sabol 2007).

## **RESEARCH OBJECTIVES**

It has been shown that schools should integrate information literacy into the context of classroom curriculum; otherwise, information literacy cannot become students' learning habits (Andretta 2005; Chen 2011; Harada & Yoshina 2004). This study attempts to investigate this issue by conducting an experiment in two junior-high classes, which accept science instruction infused information literacy using the Big6 model, and traditional teaching instruction, respectively. Students' memory and comprehension learning, as well as problem-solving skills are the focuses of this study. Specific research questions related to the purpose are as follows:

- a) Does the integrated information literacy instruction have an effect on students' ability to memorize the science content associated with the topic?
- b) Does the integrated information literacy instruction have an effect on students' ability to comprehend the scientific concepts associated with the topic?
- c) Does the integrated information literacy instruction have an effect on students' problem-solving skills?

## **LITERATURE REVIEW**

### **Integrating information literacy into instruction**

Since the concept of information literacy was introduced in 1970s, it has been promoted by numerous countries around the world. United Nations Educational, Scientific and Cultural Organization (UNESCO 2007) even suggest every nation should develop information literacy initiatives in the four key domains of education, health, business, as well as citizenship, so that their citizens can perform competitively and productively in the 21<sup>st</sup> century global information society. In other words, information literacy is considered as the important basis for lifelong learning in the age of knowledge-based economy. Furthermore, the American Association of School Librarians (AASL) developed new learning standards, entitled Standards for the 21-Century Learners, which are crucial for all learners to be successful in the present society (AASL 2009). It expanded the definition of information literacy to multiple literacies, including digital, visual, textual, and technological literacy.

However, how can we teach our students to be information literates? In which ways the information literacy can be integrated into the school curriculum?

Information literacy is the abilities to recognize, locate, evaluate, use and create effectively the needed information (AASL 2009; AASL and AECT 1998). Since these abilities are not equal to disconnected skills (e.g., computer skills), many studies suggested that information literacy is most effectively taught as an integral part of subject content learning, because the existing learning situations can provide meaningful environments for students practicing the above abilities (AASL 2009; Andretta 2005; Chen 2012; Chu, Tse and Chow 2011). In other words, the course-integrated instruction can improve students' information literacy by delivering instruction at their point of needs and recognize the real needs to link information literacy to the contexts of an assignment or a subject area.

Furthermore, many studies on information literacy found that information literacy instruction should be integrated across all content areas through inquiry-based or problem-solving learning (Chen 2011; Chu 2009; Eisenberg, Lowe and Spitzer 2004; Kuhlthau, Maniotes and Caspari 2007; Okemura 2008). Inquiry-based learning is not a method of doing activities; instead, it is an approach to the selected themes in which the posing of real questions and using multiple informational resources are positively encouraged by teachers. During inquiry, students work alone or in groups to actively discover, explore, quest, understand, synthesize, and create new deep understanding, while teachers play two key roles that are very different from the instructor role in the traditional teaching situation (Chu, Tse and Chow 2011; Corliss and Linn 2011; Loyens and Rikers 2011). The two roles are facilitators, who motivate students to develop the higher level thinking, and resource specialists, who provide the needed resources for students.

### **Big6 Model**

The Big6 model is one of the inquiry process models used by practitioners and researchers for integrating information literacy into curriculum (Chen 2010; Lowery 2005; Sabol 2007). This model provides a framework for students to learn how to complete a task or make a decision reasonably. The Big6 has six stages: Task Definition (TD), Information Seeking Strategies (ISS), Location & Access (L&A), Use of Information (UI), Synthesis (S) and Evaluation (E) (Eisenberg et al. 2000).

At the beginning of inquiry process, the scope of a problem should be defined clearly by students, and concept mapping is an effective tool in this stage of Task Definition (TD). Later, students can broadly search for information from books, journals, films, internet, and even interviewing experts (the stages of ISS and L&A). After locating and accessing the needed information, students read them and extract the appropriate ideas to the problems (the stage of UI). While using the information, strategies such as note taking, comparing, and summarizing are required. Students then synthesize all the information, draw conclusions about the problem and present their findings with proper media (the stage of S). Finally, students reflect on their performance by self-assessing the product and process. Students must recognize if the problem has been solved based on the stated criteria, and what they might do differently next time (the stage of E).

It seems that the Big6 model can be implemented easily by learners, but limited numbers of empirical studies so far have investigated its effects on students' problem solving and memory as well as comprehension of subject contents. In addition, which subject content suitable for integrating information literacy through inquiry-based learning has not been examined exclusively either.

### **Science as inquiry**

According to the National Science Education Standards (National Research Council 2000) inquiry is an important teaching method in science. It involves various classroom activities, such as posing questions, making observations, examining books and other sources of information, analyzing data, and communicating the results. Audet and Jordan (2005) stressed that teachers should lead students to ask questions and make discoveries in search for new understanding of science. Hung (2010) provided eighth graders with inquiry experiences and found that their abilities of formulating alternative hypotheses, designing experiments, etc. were better than the control group who designed the experiment based on the textbook only. In fact, the scientific inquiry is congruent to the concept of information literacy, because they both emphasize reasoning and critical thinking. Therefore, we may integrate information literacy into science curriculum through inquiry-based strategy to improve students' science learning.

### **Effects of inquiry-based teaching**

National Research Council (2000) underscored that student understanding of inquiry could not develop in isolation from science subject matter. In other words, scientific knowledge still remained important. Several review studies showed that inquiry-based teaching produced positive results on cognitive achievement, process skills, higher-order skills, and attitudes toward science (Khalid 2010; Eisenberg, Lowe and Spitzer 2004). Schroeder et al. (2007) conducted a meta-analysis of US research studies on teaching strategies published from 1980 to 2004 and found an average effect size of 0.65 of inquiry strategies on student achievement. Haury (1993) reviewed many related studies and concluded that inquiry-oriented teaching could result in outcomes that included scientific literacy, familiarity with science processes, vocabulary knowledge, conceptual understanding, critical thinking, and positive attitudes toward science. Minner, Levy, and Century (2010) also emphasized that making students actively think about and participate in the investigation process increased their science conceptual learning. A qualitative research by Chen (2011) investigated first-grade students' performance on an integrated information literacy instruction in science curriculum. It showed that students' science learning on both memory and comprehension improved through inquiry learning. Corliss and Linn (2011) developed a web-based inquiry science environment for 6<sup>th</sup> grade students and the results revealed significant learning gains in students' complex thinking about earth science concepts.

However, Chang and Mao (1998) investigated the effects of an inquiry-based teaching in earth science and found that significant higher achievement scores only at the comprehensive test, not at the factual level. National Research Council (2000) also claimed that inquiry-based teaching may not be appropriate for the goal which was for students to memorize information. In addition, an inquiry-based study conducted by Brickman et al. (2009) discovered greater improvements in inquiry students' science literacy and research skills, but these students gained less self-confidence in scientific abilities compared to the traditional students. Taraban et al. (2007) did a similar research but had different findings. They discovered that students gained significantly more content knowledge using inquiry active learning compared to traditional instruction, and students perceived greater learning gains; however, students were weak in critical thinking. Pine et al. (2006), as well as Wolf and Fraser (2008), both found that the inquiry-based learning group obtained slightly higher scores on science concepts and scientific investigations skills, but the differences were not statistically significant compared to the traditional group.

The roots of both inquiry-based and problem-based approaches can be traced back to the progressive movement, especially to John Dewey's belief (Loyens and Rikers 2011; Savery 2006). Their common characteristics included learner-centered, active learning, as well as real, meaningful and ill-structured problems or tasks. In fact, similar research results of inquiry-based learning were also found in the problem-based learning studies (PBL). Reviewing problem-based learning research from the past 30 years, Hung, Jonassen and Liu (2008) concluded that PBL curricula resulted better knowledge application and clinical reasoning skills, but performed less well in basic or factual knowledge acquisition than traditional curriculum. Furthermore, Strobel and Barneveld (2009) used a qualitative meta-synthesis approach to compare the findings of the meta-analytical research on the effectiveness of PBL. They found that problem-based learning was superior when it came to long-term retention, skill development and satisfaction of students and teachers, while traditional approaches were more effective for short-term retention.

In summary, effect studies showed mixed results with several studies reporting benefits for inquiry-based learning or PBL, while others did not find significant differences in outcome measures of subject matters. Therefore, more studies should be conducted to explore this issue.

### **Information problem-solving**

Isaksen, Dorval, and Treffinger (2011) defined problem solving as a process of closing the gap between what is and what is desired. However, information problem-solving, the Big6 model emphasized, involved a set of information-based practices, which included defining information problems, searching information, scanning information, processing information, as well as organizing and presenting information (Walraven, Brand-Gruwel and Boshuizen 2008). Students would understand that they must make effective choices in each step during the information problem-solving process. Thus, information problem-solving is a central focus of information literacy instruction on the K-12 level (Callison and Preddy 2006).

However, information problem-solving has been given little attention in schools, and direct instruction about these skills was rarely provided in curricula. Many studies showed that children, teenagers and adults have trouble with solving information problems (Walraven et al. 2008; Newell 2009). These studies advocated that there was a need to find better methods to mediate information problem-solving instruction.

Although the Big6 is an information problem-solving model, would students' problem solving skills be improved through the inquiry process using the Big6 model? This is another issue this study would like to explore.

## **METHOD**

### **Research Design**

This research employed a quasi-experimental pre-post design. Two seventh-grade classes were randomly assigned to one treatment and one comparison group. The instructional unit in both experimental and control group was taught by the same science teacher, while the former employed the integrated information literacy instruction, and the latter used the traditional teacher-led teaching strategy. The dependent variables for this study were students' memory and comprehension of science learning, as well as problem-solving skills.

Three controlled extraneous variables were the instructor, instruction time, and instructional content. Both experimental and control groups were taught the same unit of heredity by the same science teacher around three weeks, five 45-minute periods per week. The research framework of this study is shown in Figure 1.

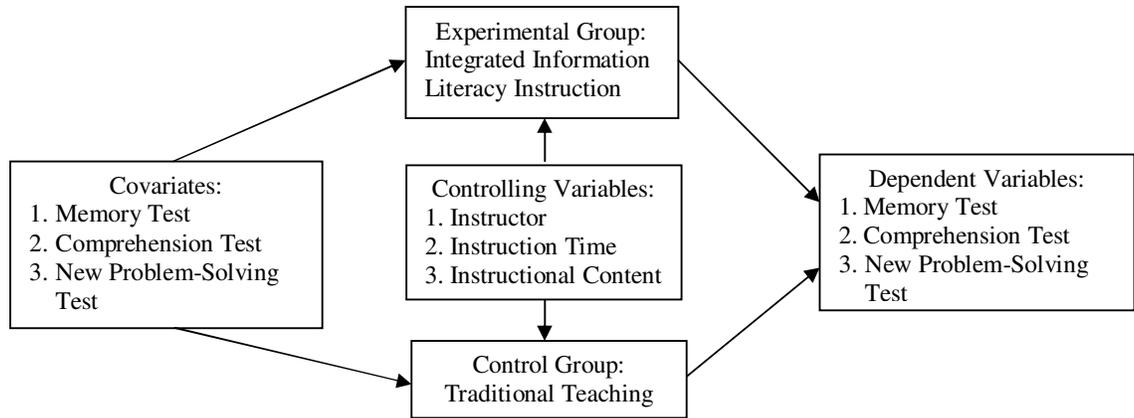


Figure 1: Research Framework of this Study

### Research Participants

Two seventh-grade classes were drawn from a public junior-high school in a rural area of Taiwan. These two classes were average classes and were similar to one another in their academic achievement according to the school's records; there were neither gifted students, nor students with special needs. There were 30 students in each class and gender was equally distributed.

### Instructional Content

The instructional content for this study was the unit of Heredity, based on the seventh-grade science textbook. An inquiry-based science curriculum infused information literacy was delivered to the experimental group. It was designed according to the Big6 model. First, the science teacher motivated students to inquire the physical characteristics which could differentiate themselves from others, so that each group of students would pose questions relating to the concept of heredity for inquiring. The teacher clearly stated the criteria for the task and provided examples of final reports with different levels of quality. This was the Task Definition stage based on the Big6 model. Then, in the stages of Information Seeking Strategies, Location & Access, and Use of Information, under the teacher's guidance, students tried to find answers to the questions through locating books and magazines in the library, using computers, as well as watching related films. Then, they put all of the useful information from different sources into a report and presented it to their peers. Finally, they reviewed their own performance during the process and wrote down their reflections in their journals. It was the Evaluation stage. If students could not find suitable answers to the questions, or read some information more interesting, they could always go back to the Task Definition stage to change their questions. In other words, the Big6 process was not linear or in a restrictive order.

Overall, this instruction emphasized both subject content and information literacy process at the same time. In the whole learning process, the teacher's role was as a coach on the side-lines who encouraged students and provided support in report preparation and oral

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presentations. Table 1 summarizes the instructional design for the experimental group, which listed weeks, periods of time, the Big6 stages, and learning activities.

On the other hand, the control group was exposed to the traditional method on the same instructional content used for the experimental group. The traditional method was teacher-centered and lecture oriented. The teacher provided the students with clear and detailed explanation, but did not ask students to raise questions, nor need to find answers through reading, viewing, and observing. The classroom activities mostly focused on memorizing the factual knowledge about heredity, such as definitions of traits and genes, etc. Table 2 summarizes the instructional design for the control group, which listed weeks, periods of time, and learning activities.

Table 1: Summary of Instructional Design for the Integrated Information Literacy in the Science Curriculum

<b>Week/period</b>	<b>Big6</b>	<b>Learning Activities</b>
Week 1 / 5 periods	TD, ISS, L&A	<ul style="list-style-type: none"> <li>○ The science teacher shared a story about Gregor Mendel's pea experiments.</li> <li>○ The science teacher encouraged students to observe their family's traits.</li> <li>○ Students formed five groups and decided the inquiry questions.</li> <li>○ Each group drew a concept map of the inquiry questions.</li> <li>○ Students brainstormed the possible information seeking strategies to find the needed information.</li> <li>○ The science teacher reviewed the information seeking strategies and locating skills for students, such as using WebPac, choosing keywords, using reference books, etc.</li> </ul>
Week 2 / 5 periods	L&A, E, UI, S	<ul style="list-style-type: none"> <li>○ Students found the needed information from various sources.</li> <li>○ Students read the found information and extracted the main points. They would consult with the science teacher to clarify the meanings of information if they could not understand it.</li> <li>○ Each group evaluated whether they needed more information about their inquiry reports.</li> <li>○ Each group synthesized their findings and wrote the reports based on the concept maps.</li> </ul>
Week 3 / 5 periods	E, TD, ISS, L&A, S, E	<ul style="list-style-type: none"> <li>○ Each group cooperatively wrote their reports using a word processing program.</li> <li>○ Each group gave an 8-minute oral report in the class.</li> <li>○ Each group evaluated the performance of other groups and themselves.</li> <li>○ The science teacher gave his comments and urged students to review the effectiveness and efficiency of the inquiry process.</li> <li>○ The science teacher encouraged students to inquire further questions about the heredity topic.</li> </ul>

Table 2: Summary of Instructional Design for the Traditional Science Curriculum

Week/period	Learning Activities
Week 1 / 5 periods	<ul style="list-style-type: none"> <li>○ The science teacher shared a story about Gregor Mendel's pea experiments.</li> <li>○ The science teacher explained the definition of traits using different visuals provided by the textbook company.</li> <li>○ The science teacher explained the Mendel's experiments and the Laws of Inheritance.</li> <li>○ The science teacher gave students worksheets for practice.</li> </ul>
Week 2 / 5 periods	<ul style="list-style-type: none"> <li>○ The science teacher described the genes' definition, functions and locations.</li> <li>○ The science teacher explained the Punnett Square to predict the expression of traits.</li> <li>○ The science teacher designed a Q &amp; A and game activity, so that students could practice the Punnett Square and understand the Law of Inheritance.</li> <li>○ The teacher gave students worksheets for practice.</li> </ul>
Week 3 / 5 periods	<ul style="list-style-type: none"> <li>○ The science teacher depicted the knowledge of chromosomes and blood types.</li> <li>○ The teacher explained how to predict the blood types of the offspring generation.</li> <li>○ The teacher gave students worksheets for practice.</li> </ul>

### Research Instruments

Three research instruments were administered in this study; namely the Memory Test, the Comprehension Test, and the New Problem-Solving Test. The first two were science achievement tests designed by the researchers. One professor in biology and one junior-high science teacher were invited to evaluate every test item to ensure the content validity of the two tests. The researchers revised the test items according to the two experts' suggestions. The third instrument was a standard test designed by Jan and Wu (2007), who adapted this test from the Test of Problem Solving (TOPS) (Zachman et al. 1984). The New Problem-Solving Test was text-oriented and the problem situations were more relevant to Taiwan's social circumstances compared to the original version. The three instruments are detailed below:

- a) The Memory Test: There were 25 multiple-choice items, which measured students' memory of the learned subject content, such as the knowledge about heredity, gene, and traits. The internal consistency reliability coefficient of the test was .853 (KR-20= 0.853). Some example items are listed in Appendix A.
- b) The Comprehension Test: It was composed of 22 multiple-choice questions, which required students to transfer their understanding of scientific concepts covered in the instruction to a new context. For example, according to the blood types of the parental generation, students were asked to predict the offspring's blood types, or vice versa. Its reliability coefficient was .838 (KR-20= 0.838). Some example items are listed in Appendix B.
- c) The New Problem-Solving Test: It was designed to test students how to define a question, propose solutions, and avoid facing the same problems. There were six problems which included a problem description and two to three related open questions. Each question required students to address the best three answers. Its reliability coefficient was .91 (Cronbach's  $\alpha = 0.91$ ) and the inter-judge agreement was  $r = 0.93$ . Its correlation coefficient to the subjects of science, mathematics, social studies, and Chinese achievements were  $r = 0.54, 0.40, 0.58,$  and  $0.51$  ( $p < .000$ ), respectively. It meant that the test had good reliability and validity. Some sample questions are presented in Appendix C.

### **Procedure**

Two seventh-grade classes from a public junior-high school were selected and randomly assigned to the experimental group and control group. Then they received three pretests (memory, comprehension and problem-solving tests) to determine their prior knowledge levels in the instructional content, and problem-solving skills. Next, the experimental group accepted an inquiry-based science curriculum infused information literacy using the Big6 model, while the control group accepted the traditional instruction. The instruction unit, taught by the same science teacher lasted for three weeks. After the completion of the instruction, both groups received three posttests (the same pretests with different item orders).

### **Data Analysis**

Due to the limitations in practical conduct of research in the public school settings, it was impossible to randomly assign individual students to treatments in this study. Instead, intact classes of students were used. The data was analyzed using an analysis of covariance (ANCOVA) on posttest scores with the three pretests as the covariates to determine any significant differences between the experimental group and the control group.

## **RESULTS**

### **Analysis of Memory Test Results**

There were two achievement tests used in this study to measure students' science learning; they were memory test and comprehension test. The results of descriptive statistics for memory test are presented in Table 3. Before further investigating the performance between the two groups via analysis of covariance, it is necessary to conduct the relationship between the dependent variable and the covariate. The homogeneity of regression was tested and the result showed that the homogeneity between two groups was not significant ( $F=2.27$ ,  $p= 0.14 > 0.05$ ). It meant that these two groups were homogenous. Hence, the analysis of covariance in memory test could be conducted. Summary ANCOVA statistics were shown in Table 4. As shown in Table 4, the obtained F ratio was not significant ( $F= 0.04$ ,  $p= 0.85 > 0.05$ ). This indicated that the inquiry-based science curriculum infused information literacy was not able to improve seventh-grader's memory achievement compared to the traditional lecture-led method.

Table 3: Pretest Mean, Posttest Mean, Adjusted Mean in Memory Test

Group	N	Pretest		Posttest		Adjusted M
		M	SD	M	SD	
Experimental Group	30	15.93	2.73	19.33	2.83	17.42
Control Group	30	11.37	2.77	14.97	2.99	17.32

Table 4: Analysis of Covariance in Memory Test

Source	SS	df	MS	F	p	$\eta^2$
Treatment	0.07	1	0.07	0.04	0.85	0.001
Error	108.64	57	1.91			

$\alpha=.05$

### Analysis of Comprehension Test Results

The means, standard deviations, and adjusted mean for the comprehension test results are shown in Table 5. The homogeneity of regression was tested and the result showed that the homogeneity between the two groups was not significant ( $F= 2.47, p= 0.12 > 0.05$ ). It meant that these two groups were homogenous. Hence, the analysis of covariance in comprehension test could be conducted. The ANCOVA statistics summary is shown in Table 6 where the obtained F ratio was significant ( $F= 41.09, p= 0.00 < 0.05$ ). To understand this effect in practice, the effect size was measured and the obtained  $\eta^2$  was 0.42 which is large ( $> 0.14$ ), according to Cohen (1988). The large effect size means having large impacts on a practical level. In other words, the inquiry-based science curriculum infused information literacy is able to improve seventh-grader’s comprehension achievement compared to the traditional lecture-led method.

Table 5: Pretest Mean, Posttest Mean, Adjusted Mean in Comprehension Test

Group	N	Pretest		Posttest		Adjusted M
		M	SD	M	SD	
Experimental Group	30	7.73	2.50	13.20	2.93	12.55
Control Group	30	6.37	1.50	9.07	2.32	9.95

Table 6: Analysis of Covariance in Comprehension Test

Source	SS	df	MS	F	p	$\eta^2$
Treatment	99.01	1	99.01	41.09	0.00	0.42
Error	137.36	57	2.41			

$\alpha=.05$

### Analysis of Problem-Solving Skills Results

The results of descriptive statistics are presented in Table 7. The homogeneity of regression was tested and the result showed that the homogeneity between the two groups was not significant ( $F= 2.44, p= 0.12 > 0.05$ ). It meant that these two groups were homogenous. Hence, the analysis of covariance could be conducted. The summary for ANCOVA statistics is shown in Table 8 where the obtained F ratio was significant ( $F= 17.76, p= 0.00 < 0.05$ ) and  $\eta^2$  was 0.23. According to Cohen (1988), the obtained  $\eta^2$  was large ( $> 0.14$ ), meaning that this effect is meaningful in practice. In other words, the inquiry-based science curriculum infused information literacy is able to improve seventh-grader’s problem-solving skills more effectively than the traditional lecture-led method.

Table 7: Pretest Mean, Posttest Mean, Adjusted Mean in Problem-Solving Test

Group	N	Pretest		Posttest		Adjusted M
		M	SD	M	SD	
Experimental Group	30	110.83	13.69	115.07	12.15	103.81
Control Group	30	84.73	21.06	88.23	19.48	100.27

Table 8: Analysis of Covariance in Problem-Solving Test

Source	SS	df	MS	F	p	$\eta^2$
Treatment	100.26	1	100.26	17.76	0.00	0.23
Error	321.76	57	5.65			

$\alpha=.05$

## DISCUSSION

The data analyses of this study indicate that the experimental group performs significantly better than their counterparts on the problem-solving and comprehension tests, but not on the memory test. In other words, the integrated information literacy instruction using the Big6 model can help seventh-graders effectively solve information problems as well as gain a deep understanding of scientific concepts. As for students to memorize factual scientific information, the inquiry-based teaching only performs as equal as the teacher-led teaching.

It has been suggested that information literacy should be integrated into regular curriculum through inquiry-based learning to improve students' information literacy and content learning (AASL 2009; Andretta 2005; Chen 2012; Chu, Tse and Chow 2011; Eisenberg, Lowe and Spitzer 2004). The results of the present study support this affirmation. The integrated information literacy instruction in this study is designed based on the Big6 model, which emphasizes critical thinking and reasoning. During the scientific inquiry process, students have to define their information problems, then search, read and organize needed information through a systematic process of thinking; lastly students present their findings, as problem solving process does (Walraven, Brand-Gruwel and Boshuizen 2008). Therefore, students' problem solving skills can be improved during the instruction. On the whole, the six stages of the Big6 model provide a user-friendly framework for seventh-graders to solve complex tasks. Thomas, Crow, and Franklin (2011) indicate that one of the Big6 model's major advantages is its apparent simplicity, which helps students grasp inquiry process as a whole. Newell (2009) alleges that the Big6 model may become one of the selected choices for mediating information problem-solving instruction.

In this study, students in the experimental group select their topics of interest for inquiry, such as gene, chromosome, and various traits. The science teacher guides students to locate relevant resources and encourages them to compare, extract and synthesize the needed information in order to answer their own questions. Therefore, the findings in comprehension learning of this study verify what many studies have revealed that integrating information literacy into curriculum through inquiry-based strategies helps students develop higher-order thinking skills (Chen 2011; Hung, Jonassen and Liu 2008; Strobel and Barneveld 2009).

Compared to the traditional lecture-based learning, the inquiry-based learning deemphasizes recall of the factual information. During the three-week instruction, students in the experimental group pay most of their attention to solving information problems, while the control group receives lectures about heredity topics and practices related worksheets. Therefore, the present study supports the assertion saying that the inquiry-based learning may not be the best choice for improving learners' factual information acquisition compared to the traditional teaching (Chang and Mao 1998; Hung, Jonassen and Liu 2008). However, these findings are not consistent with a pre-post study of integrating information literacy into first-grade science class (Chen 2011). The latter indicates that first-grade students' remembrance of factual information and comprehension of scientific

concepts both are enhanced through inquiry learning. A possible reason for the differences could be attributed to most of the inquiry questions posed by first graders being factual level, such as “What did ants eat?” and “Where did bees live?” During the inquiry process, what first-graders read and think are all about factual knowledge contents. On the contrary, in the present study, seventh-grade students pose more higher-order questions (e.g., What kinds of diseases are hereditary? What causes them? Do environmental factors play roles during inheritance processes?). They actively think about these higher-order questions and try to solve them through synthesizing information from multiple resources.

In summary, the most important contribution of this study is to verify that a person’s comprehension of subject contents and problem-solving skills can be improved through the integrated information literacy instruction using the Big6 model. Although the experimental group does not perform significantly better than their counterparts on the memory test, this teaching strategy performs as equal as the traditional instruction. In other words, the instructional time used for inquiry-based teaching is not detrimental to the learning of subject contents. More important, the inquiry-based teaching improves students’ critical thinking and problem solving skills, in addition to the factual information gaining of subject matters.

## **CONCLUSION**

Schroeder et al. (2007) conclude from a meta-analysis research that no one strategy is as powerful as using a combined strategies approach. From the results of this study, the integrated information literacy instruction in science curriculum improves students’ learning on comprehension and problem-solving skills, but not on factual information acquisition. This alternative teaching strategy exhibits positive effects on student achievement when compared with the traditional teaching method. Although the teacher-led rote teaching method is common in Taiwan, combining alternative teaching strategies in curriculum, such as integrated information literacy instruction would be an innovative teaching method today.

Based on the findings of this study, the following recommendations are made for future research on information literacy instruction:

- a) Integrated information literacy science curriculum using the Big6 model can improve students’ comprehension and problem-solving skills.
- b) Science teachers may design curricula using both inquiry- and lecture-based methods, so that students can acquire scientific concepts and factual information at the same time.
- c) Further empirical studies can be carried out on the relationship among age, subject contents, and integrated information literacy instruction.

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**Appendix A**

Memory Test (sample items)

1. ( ) Which scientist proposed the Laws of Inheritance?  
(A) Charles Darwin (B) Robert Hooke (C) Carl von Linne (D) Gregor Mendel.
2. ( ) Which kind of material determines the traits of organisms?  
(A) chromosomes (B) cell (C) gene (D) nucleus of cell.
3. ( ) Among the following items, which item can include the other three items?  
(A) egg (B) chromosomes (C) gene (D) DNA
4. ( ) Who can determine the sex of a baby?  
(A) mother (B) father (C) mother and father (D) It depends.
5. ( ) In genetics, what are a person's height, eye-color and skin-color called?  
(A) genes (B) mutations (C) traits (D) personalities

**Appendix B**

Comprehension Test (sample items)

1. ( ) Which one is correct among the following statements about heredity?  
(A) The number of dominant genes must be larger than the recessive genes. (B) Among all inherited disorders, dominant gene is normal and the recessive gene is abnormal. (C) High plant stalk is dominant, while short stalk is recessive. (D) If both parents are recessive, it is impossible that their offspring is dominant, unless mutation happens.
2. ( ) Mary has blood type O. Her father has blood type A. How many possible blood types that Mary's mother may have?  
(A)1 (B)2 (C) 3 (D)4
3. ( ) In a hospital, there were two couples who gave birth to a baby on the same day. Both Mr. & Mrs. Lin had type A blood, while Mr. & Mrs. Cheng had type AB blood. A careless nurse mislabeled three new born babies. Baby X's blood type is O; Baby Y's blood type is B; Baby Z's blood type is AB. Please help these three babies find their parents.  
(A) Baby X is in Lin's family, while Babies Y and Z are in Cheng's family (B) Baby Y is in Lin's family, while Babies X and Z are in Cheng's family (C) Babies X and Y are in Lin's family, while Baby Z is in Cheng's family (D) Babies X and Z are in Lin's family, while Baby Y is in Cheng's family
4. ( ) The skin color is determined by two pairs of heredity genes (A, a & B, b). The dominant genes A and B will make skin darker. With the following different gene types, who has the whitest skin?  
(A) AaBb (B) AaBB (C) Aabb (D) aaBB.
5. ( ) Two tall vine pea plants were hybridized. There were 290 plants which had tall vine, and 95 plants which had short vine in the offspring generation. What genotypes are in the parental generation?  
(A) TT x TT (B) TT x Tt (C) Tt x Tt (D) tt x tt

New Problem-Solving Test (sample items)

1. Shou-Hua was working on his homework at 9:00 p.m. All of a sudden, the light went out, and it was very dark. Shou-Hua worried, "If I did not finish the homework before I go to sleep, I would be punished by teacher tomorrow."

(1) What should Show-Hua do now?

- A1:
- A2:
- A3:

(2) What are the possible reasons why the light went out?

- A1:
- A2:
- A3:

(3) What should Shou-Hua do to avoid the same situation happening again?

- A1:
- A2:
- A3:

2. Chi-Chung and his wife drove to a supermarket. When they got there, they found out that the parking lot was full. There was no parking space near around either.

(1) What should they do now?

- A1:
- A2:
- A3:

(2) What should they do to avoid the same situation happening again?

- A1:
- A2:
- A3:

3. Shin-Mang went shopping on Sunday. She first went to a bookstore and bought a magazine. Then she went to an eatery to eat lunch. When she paid the bill, she could not find her purse.

(1) What are the possible reasons for Shin-Mang losing her purse?

- A1:
- A2:
- A3:

(2) What should Shin-Mang do to avoid the same situation happening again?

- A1:
- A2:
- A3: