Effects of Inquiry-based Instruction: Case Study of a Marine Technology School

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ABSTRACT

This aim of this study was to explore the learning effectiveness of inquiry-based instruction among vocational high school students. The sample consisted of 20 students at a maritime polytechnic vocational high school in southern Taiwan, and the instruction focused on the laboratory practices for assembling and disassembling power equipment. We used a single-group design and conducted pre- and posttests to measure changes in basic capabilities, motivation for and interest in studying science, and performance on a skill examination table.

The study results indicate that inquiry-based instruction significantly improved the basic academic abilities and skills of students. This improvement was especially pronounced with respect to the self-efficacy and performance goal dimensions related to the motivation to study science. No significant differences were found for the three dimensions related to interest in studying science attitude toward science, learning atmosphere, and student engagement.

Keywords: Inquiry-based instruction, Science learning, Learning effectiveness

INTRODUCTION

The rapid pace of technological and scientific advancement constitutes a megatrend that has come to dominate the training of workers for and the very nature of various enterprises. In this context, the educational aims of vocational education are not only to provide students with those skills that are currently needed for participation in the production sectors but also to train students to think so that they can succeed in the increasingly complex environments and the multiplicity of trends in which many enterprises operate.

The Republic of China's Ministry of Education issued the report "Reshaping Technological–Vocational Education, Section II" providing policies to facilitate the use of vocational education to help students acquire the skills required by various industries and to provide workers for high-tech sectors. The report addresses the use of flexible curricula, selection by substantial practices, the enhancement of pragmatic skills, and the reshaping of careers. Furthermore, the National Science Council of the Republic of China also proposed the High Scope Program in 2006 to help middle schools use newly developed technology to design curricula and adopt inquiry-based instruction. It encouraged students' self-motivated problem-solving, curiosity about science, and motivation to learn, and it established a learning model designed to facilitate student-initiated exploration and thinking.

The United States National Research Council (NRC) has already established inquiry-based instruction as one of the teaching standards for science education. This approach is among the most important methods adopted by science educators (Banerjee, 2010).

The learning activities involved in scientific exploration may benefit students by helping them develop critical thinking skills and individual knowledge structures (Schneider, Krajcik, Marx, & Soloway, 2002). Thus, inquiry-based instruction may help students understand how to identify problems, autonomously seek answers, and develop and verify solutions. These skills are so-called "portable capabilities," a status that underscores their importance. The use of "inquiry" to describe this approach refers to its reliance on an active learning process that allows students to answer research questions via data analysis (Bell, Smetana, & Binns, 2005). Inquiry-based instruction is student oriented, although instructors may direct students at appropriate times according to the requirements of the situation. Beginners may need more instruction so that they can engage in the process of inquiry more effectively (Zangori, Forbes, & Biggers, 2012). In regard to content, the NRC asserted that inquiry involves five processes: hypothesizing, investigating, observing, interpreting, and evaluating (Banerjee, 2010). According to Wheeler and Bell

(2012), inquiry involves a different set of five processes related specifically to identifying a problem: collecting data, interpreting data, developing alternative interpretations, presenting results, and verifying results. Additionally, inquiry can be categorized into the following four types: (1) verification inquiry, where a set of questions, approaches, and solutions is provided by instructors; (2) cascades of structure; (3) guided inquiry, where instructors provide questions for further inquiry; and (4) open inquiry. Moreover, Wheeler and Bell (2012) also noted the possible influence of certain myths about inquiry-based instruction. One of these is that although this approach may be helpful for students, it is difficult for instructors to implement. In fact, this method is appropriate for science education at any level and for any grade.

Considerable research has been conducted on inquiry-based instruction. For example, Gormally, Brickman, Hallar, and Armstrong (2011) implemented an inquiry-based curriculum in a college biology laboratory classroom, and Marshall, Lotter, Smart, and Sirbu (2011) performed a comparative analysis of two inquiry-based observational protocols to better understand the quality of teacher-facilitated inquiry-based instruction. Additionally, Marshall and Horton (2011) explored the relationship between inquiry-based instruction and higher-order thinking in students. Moreover, Wang, Wang, Tai, and Chen investigated the effectiveness of inquiry-based instruction among students with different levels of prior knowledge and reading abilities. The present study was based on a call issued by the High Scope Program of the National Science Council of the Republic of China to conduct experiments in inquiry-based instruction teaching with the aim of understanding the learning efficacy of inquiry-based instruction among vocational high school students, focusing particularly on basic capabilities in specific subjects, motivation for and interest in studying science, interest in inquiry-based instruction, and the ability to apply scientific skills to specific subjects.

RESEARCH DESIGN AND IMPLEMENTATION

1. Participants

The study sample, which was selected using purposive sampling, consisted of third-year students in two classes at a vocational school in southern Taiwan. Of the 72 students in the two classes, the 20 attending the course on laboratory practices for disassembling and assembling power equipment (hereafter, "Power Operation course") from September to December in 2012 were chosen to participate in this study.

2. Description of instruction

The Power Operation course examined in this study was primarily focused on laboratory practices. The pedagogical process underpinning inquiry-based instruction includes sections emphasizing motivation, instruction, collective lab practices, group lab practices, inspiration, review questions posed by students, additional practices, verification, and interpretation. For example, the instructor in the Power Operation course attempted to increase students' motivation by asking questions such as "Why can't the engine be disassembled?" and "Why can't the engine be assembled?" and so on.

3. Research instruments

The following four research instruments were employed in this study:

(1) Cognitive domain: Basic capabilities

The examination in this domain included 10 multiple-choice questions and five inquiry-based questions based on the theories presented in the "two-way specification table." It tested three cognitive "layers" that were addressed in the course: theory, operation, and application. It subsequently posed questions about subtopics within these three layers.

(2) Affective domain: Motivation for and interest in learning science

The questionnaire used to examine this domain was based on the Learning Motivation Scale for Elementary School Nature and Life Technology Courses and the Questionnaire on Learning Interest for Elementary School Science Courses developed by Wu (2007), both of which have excellent validity and effectiveness. The motivation tool includes five dimensions: self-efficacy orientation, learning-goal orientation, performance-goal orientation, value orientation, and learning participation; these dimensions have also shown excellent validity and effectiveness. These questionnaires used a five-point Likert scale, and higher scores reflect more motivation for or interest in learning science.

(3) Psychomotor domain

As this study was specifically designed to measure skills, we used self-edited skill examination tables involving four tasks: replacing an engine, replacing a continuously variable automatic transmission mechanism, replacing tubeless tires, and replacing disc brake pads (shoe linings).

4. Domain context

This study was conducted at one of four maritime affairs vocational school in Taiwan; the school used in the study is located in southern Taiwan. This study was designed to support the High Scope Program promoted by the National Science Council of the Republic of China, which emphasizes the integration of new scientific and technological developments into school curricula and teaching as part of its mission. Schools participating in the High Scope Program must formulate innovative instructional programs for newly developed technologies and employ inquiry-based instruction to conduct a three-stage program including a trial of the instructional approach, an experiment to test its effectiveness, and appropriate modifications of the approach. The results of this experiment may be applied to other maritime affairs vocational schools. The main purpose of inquiry-based instruction is to develop students' ability to formulate questions, actively explore, and solve problems.

5. Data analysis

All data collected for this study were analyzed with a commercially available SPSS program. The statistical analyses included descriptive statistics, means, standard deviations, and *t*-tests.

RESULTS

1. Cognitive domain

Table 1 presents the results of the basic capability pretest and posttest for the Power Operation course. Table 1 shows that the mean score significantly improved, from 23 to 96.6, between the pretest and the posttest.

Table 1 Results of Basic Capability Pretest and Posttest among Vocational School Students in the Power Operation Course (*N* = 20)

	Pretest (*n* = 20)		Posttest (*n* = 20)		*t*	*p*	95%CI	
	M	*SD*	*M*	*SD*			LL	UL
Basic capability examination	23.00	5.93	96.50	4.01	-50.88	*P < .001*	-76.52	-70.48

2. Affective domain (motivation to learn science)

Table 2 presents the pretest and posttest results regarding vocational students' motivation to learn science. Table 2 shows that the mean self-efficacy score on the pretest was 3.68 and that on the posttest was 4.17.

Table 2 Results of Pretest and Posttest regarding Motivation to Learn Science among Vocational School Students in the Power Operation Course (*N* = 20)

Motivation to learn science	Pretest (*n* = 20)		Posttest (*n* = 20)				95%CI	
	M	*SD*	*M*	*SD*	*t*-value	*P*-value	LL	UL
Self-efficacy	3.68	.58	4.17	.54	-3.72**	*p < .01*	-.77	-.22
Learning-goal orientation	4.03	.56	4.25	.56	-1.39	*p > .05*	-.56	.11
Performance-goal orientation	3.29	.33	3.76	.67	-2.98**	*p < .01*	-.79	-.14
Value orientation	4.27	.49	4.33	.54	-.51	*p >. 05*	-.31	.189
Test anxiety	3.41	.47	3.33	.57	.50	*p >. 05*	-.25	.41

3. Affective domain (interest in learning science)

Table 3 presents the results of the pretest and posttest regarding interest in learning science. The mean score for attitude toward science on the pretest was 2.69 and that on the posttest was 3.89.

Table 3 Results of Pretest and Posttest regarding Interest in Learning Science among Vocational School

Students in the Power Operation Course (*N* = 20)

Interest in learning science	Pretest (*n* = 20)		Posttest (*n* = 20)		*t*	*p*	95%CI	
	M	SD	M	SD			LL	UL
Attitude toward science	2.69	.434	3.89	.55	-6.39***	*p* < .001	-1.59	-.81
Learning atmosphere	3.20	.260	4.05	.67	-6.36***	*p* < .001	-1.13	-.57
Difficulty of learning	3.22	.282	2.28	.62	5.68***	*p* < .001	.59	1.29
Commitment to learning	3.34	.284	3.94	.63	-4.51***	*p* < .001	-.88	-.32
Participation in learning	3.59	1.27	3.76	.58	-.49	*p* > .05	-.90	.56

4. Skills domain

Table 4 presents the pretest and posttest results related to students' skills. The data reveal a significant improvement between the pretest (*M* = 26.24) and posttest (*M* = 94.53). The results of a *t*-test examining whether inquiry-based instruction improved students' skills showed a significant change (*t*=-84.82, *p* < .001) between the pre- and posttests, indicating that inquiry-based instruction had a significantly positively effect on students' skills.

Table 4 Results of Skills Pretest and Posttest among Vocational School Students in the Power Operation Course (*N* = 20)

	Pretest (*n* = 20)		Posttest (*n* = 20)		*t*	*p*	95%CI	
	M	*SD*	*M*	*SD*			LL	UL
Skills examination	26.24	3.59	94.53	2.40	-84.82***	*p < .001*	-69.97	-66.60

DISCUSSION

This study confirmed that inquiry-based instruction can significantly improve students' cognitive ability and skills. In addition to the direct influence of inquiry-based instruction, we found improvement related to the use of a two-way specification table by teaching staff, who employed this tool to develop questions for the basic ability examination. Thus, assisting instructors with their pedagogical approaches and assessment techniques can indirectly lead to significant improvements in student performance.

The comparison of pre-test and posttest scores for self-efficacy, learning-goal orientation, and performance-goal orientation reflected considerable enhancement of students' motivation to learn science. The data also showed that students experiencing difficulty with learning could be helped by inquiry-based instruction. Moreover, given that self-efficacy is strongly associated with self-confidence related to learning science, it is likely that inquiry-based instruction encourages students to adopt different approaches in the service of developing a better understanding of the subject, helps students familiarize themselves with ongoing experiments and areas of inquiry, and enables them to obtain better scores on examinations.

In terms of "value orientation," this study found no change in students "value orientation" toward science, a construct related to students' appreciation of the value of science learning. This may have been caused by students' lack of experience with inquiry-based instruction and the longstanding tendency of vocational education to focus only on skills rather than on the process of thinking. However, students in the Power Operation course changed significantly with regard to their interest in learning science, as manifested by scores for attitudes toward science, learning atmosphere, commitment to learning, and difficulty with learning. These data reflect increased interest in and decreased difficulty with learning science among students taking the Power Operation course.

We also found no significant differences in learning participation, which is consistent with the results reported by Zangori, Forbes, and Biggers (2012). This may be attributed to the relatively short duration of the teaching period in this study. Additionally, students in this study were in the initial stage of learning. Moreover, the teaching environment in Taiwan may emphasize a linear conception of progress and the use of examinations to advance in school. This creates a culture in which students must focus on receiving what is taught by the faculty at the expense of asking questions. All of these factors may lead to significantly less participation in learning.

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