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Problem-Solving Abilities Produced in Project Based Technology Education

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The purpose of this study was to determine and clarify the relationships between the structure of learning activities and the development of problem-solving abilities in project based technology education in Japan.

There is a range of approaches that support teaching-learning processes in technology education, for example, the project based approach, modular approach, integrated approach, and so on. One of the most popular and current approaches in the United States is the modular approach, which typically provides students with guidance and resources for activities and evaluation. Students rotate from station to station, for example, CAD, CNC, robotics, and so on (Daugherty, 1998). The integrated approach is an instructional method that incorporates the idea of unity between forms of knowledge and respective disciplines (Pring, 1973). This approach also emphasizes the need for inter-disciplinary learning and its connection with the real world (Loepp, 1999).

On the other hand, the project based approach is a method that gives students the opportunity to work in a "plan-do-see" manner, using tools, machines, materials, and processes. The project can be defined as a constructive activity with a purposeful action. This well-established approach, the origin of which can be found in the American progressive education movement, expanded throughout the world during the 20th century as a result of international reforms in education (Knoll, 1997). In Japan, most technology teachers in junior high schools have adopted the project based approach rather than the modular approach or integrated approach.

The Japanese Ministry of Education, Science, Sports and Culture (MESSC) published the *Course of Study* in 1998. This publication has provided the framework for the current curriculum in Japan (MESSC, 1998a). The objective of technology education in Japan is "to make students understand the role of technology, acquire knowledge and skills of manufacturing, energy utilization and computing, and develop the abilities and attitudes to use the knowledge and skills effectively." The *Course of Study* also recommended instruction based on practical and empirical projects and purposeful problem solving. It was also expected that, through this strategy, students would develop a sense of pleasure in undertaking projects.

One example of the project based approach was implemented in Nagano Junior High School, attached to Shinshu University. Within the scope of the project, students decided that they would send some gifts to students in a special school near the junior high school. The students visited the special school in order to research the requirement. They were divided into six teams of six students, and each team developed its plans for the gifts and manufactured the products. The students spent a total of three months on the project. On completion of the project, they sent the gifts, consisting of shoe boxes, shelves, a magazine rack, and so on, to their handicapped friends in the special school (Moriyama et al., 2001). Further projects, involving the development and making of a CD rack, pencil holder, Web site, lamp, and moving toys, were implemented throughout Japan. At the same time, student involvement in other design and implementation projects, particularly a robot contest, also increased gradually The project based approach, such as that involved in the above examples, has various learning activities, and students can develop their problem-solving abilities through experience in each learning activity. However, it is obvious that the project based approach needs particular levels of student competencies. Jyou (1992) examined the structure of students' self-evaluation competencies and suggested that these competencies supported learning activities as metacognition. These relationships can be demonstrated as outlined in Figure 1.

Practices adopted in the project based approach need to be evaluated

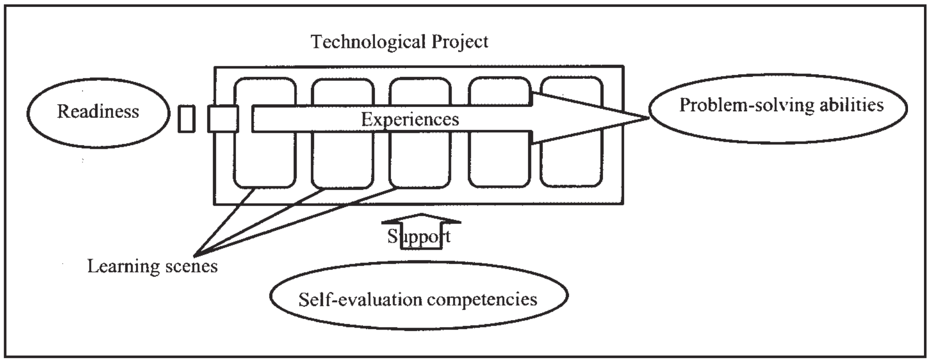

Figure 1. The search model.

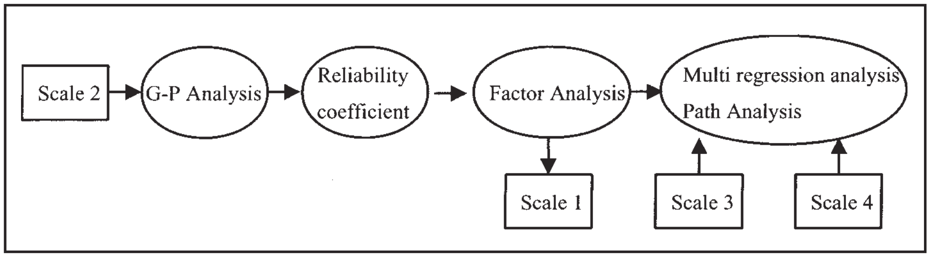

Figure 2. The procedure for data analysis.

from the viewpoint of whether they succeed in promoting problem-solving abilities or not. However, so far there have been no studies that have tried to clarify the influences of each of the factors shown in Figure 1. It is expected that the relationships should suggest the feature of the project based approach. Therefore, the goal of this study was to answer the following questions:

- What kind of learning activities are involved in a technological project at the junior high school level?
- How do students' self-evaluation competencies support their learning activities?
- How do students' learning activities contribute to the development of their problem-solving abilities?

Methodology

Subjects

The subjects for the study were 544 junior high school students (1–3 grades) in Nagano Prefecture, Japan. These subjects had studied woodworking in Grade 1, electronics in Grade 2, and agriculture, metalworking, and information basics in Grade 3.

Instruments

Three scales used in the study measured (a) students' learning activities, (b) students' self-evaluation competencies, and (c) students' problem-solving abilities. Following is a description of the scales used in this study.

Scale 1: Learning Activities

According to the DeLuca (1992) problem-solving model, five activities are related to workers' technological projects: trouble shooting, scientific process, design process, project management, and research and development. While the process of R&D is not included in Japanese technology education at the junior high school level, trouble shooting, scientific process, design process, and project management are included. Therefore, four activities and 19 associated statements, excluding reference to the R&D, were selected for this study as follows:

- Trouble shooting: Isolate the problem, identify possible causes, implement a solution, test the solution.
- Scientific process: Observation, develop hypotheses, experimentation, draw conclusions.
- Design process: Ideation, brainstorming, identify possible solutions, prototyping, final design.
- Project management: Identify tasks to reach goal, develop a plan to accomplish tasks in each classroom activity, plan a sequence of procedures in each task, implementation of the plan, evaluation of the implementation, modification of the plan.

Subjects answered the 19 statements, choosing one of the four responses: 4 (*I have experienced that a lot*), 3 (*I have experienced that a little*), 2 (*I have almost no experience of that*), 1 (*I have not experienced that at all*).

Scale 2: Self-Evaluation Competencies

According to the results of an investigation by Jyou (1992), three factors are involved in students' self-evaluation competencies. In this study, six statements that would obtain a high factor loading from each factor were selected. The three factors and associated statements included:

- Competencies in self-monitoring: Analyzing myself objectively, understanding my own characteristics, understanding my own abilities.
- Intentions to reach the goal: Progressing to learn individually, strong motivation, investigating unknown things individually.
- Competencies of creating criterion: Understanding functions of self-evaluation, utilization of results of self-evaluation, discovering the learning strategies by myself.

Subjects answered the statements, choosing one of the three responses: 3 (*I think I have that competence very much*), 2 (*I think I am average*), 1 (*I think I don't have that competence at all*).

Scale 3: Problem-Solving Abilities

MESSC (1998b) defined concepts of problem-solving abilities in Japanese technology education as abilities in discovering tasks from daily life, considering various solutions, gathering information, decision making, implementing according to the selected plan, evaluating the results of implementation, and having the responsibilities for these results. Based on these concepts, the following eight

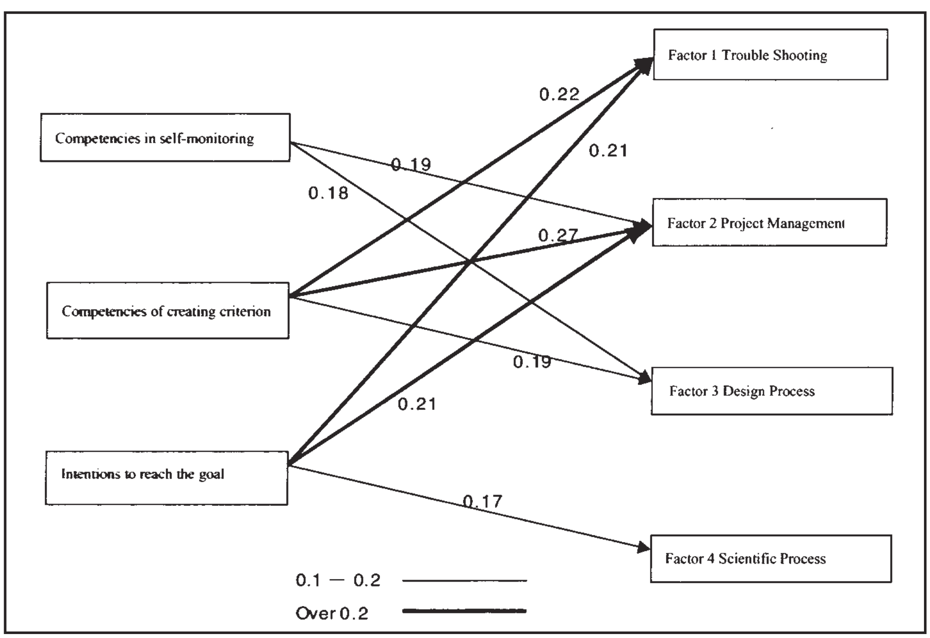

Figure 3. Path diagram between self-evaluation competencies and structure of learning scenes.

statements were prepared for this study:

- An ability in observing from daily life.
- An ability in discovering tasks by oneself.
- An ability in developing new ideas.
- An ability in judging the correct method.
- An ability in making the plan adequately.
- An ability in implementing effectively.
- An ability in devising improvements.
- An interest in technological equipment or devices.

Subjects answered these statements, giving one of the following responses: 3 (*I think I get that ability through my project*), 2 (*I think I am average*), 1 (*I think I don't get that ability through my project at all*).

Data Analysis

The procedure for data analysis is shown in Figure 2. First, the item discriminating powers of each statement in Scale 1 were analyzed by G-P analysis (both 50%). Also, the reliability of this scale was confirmed by the reliability coefficient obtained by using the KR-20 (Kuder-Richardson) formula. Next, a factor analysis using the principal factor method and normal varimax rotation was implemented in order to determine the structure of learning activities in students' projects. Additionally, path analyses were employed for considerations of contributions of the self-evaluation competencies to the learning activities and the learning activities to the problem-solving abilities.

Results and Discussion

As a result of the investigation, we obtained 472 effective answers (86.8% of the total). The item discriminating powers and reliability were confirmed on Scale 1 (KR-20 = 0.83).

The Structures of Learning Activities in the Project at the Junior High School Level

As a result of factor analysis, four factors were found: Factor 1: Trouble Shooting, Factor 2: Project Management, Factor 3: Design Process, and Factor 4: Scientific Process (see Table 1). However, brainstorming, prototyping, and drawing conclusions were not loaded on each factor. The mean scores of brainstorming and prototyping were indicated as low level, and it appeared that Japanese technology teachers were not giving students enough opportunities for these learning activities. By contrast, the mean score of drawing conclusions was indicated as high level and seemed to be an everyday occurrence in the classroom. It was evident that the structure of learning activities in the project based approach was coincident with that of the modified DeLuca model which was constructed from four factors. Also, the order of mean scores of these factors indicated that manufacturing activities were central to the students' projects. However, scientific or analytical exploration, associated with technological concepts, was only slightly experienced by students, $F(3,1884) = 52.12$, $p < 0.01$.

Self-Evaluation Competencies Support the Learning Activities

In the path analyses between self-evaluation competencies and their learning activities, strong paths from *competencies of creating criterion* and *intentions to reach the goal* to Factor 1 (Trouble Shooting) were obtained. Also, the paths to Factor 2 (Project Management) were obtained from all self-evaluation competencies. Regarding Factor 3 (Design Process), there were weak paths from *competencies of self-monitoring* and *competencies of creating criterion*. However, the only path to Factor 4 (Scientific Process) was from *intentions to reach the goal*, whose effect was weak (see Figure 3).

These results suggest that the students' projects were supported by self-evaluation competencies and, especially, that students' strong motivation to reach their goals and generating their own criteria contributed to their performances in the areas of trouble shooting and project management.

Project Based Approach Produces Problem-Solving Abilities

Trouble shooting and project management. The results of path analyses between the learning activities and the problem-solving abilities, contributions of Factor 1 (Trouble Shooting) and Factor 2 (Project Management), are indicated in Figure 4. The strong paths from Factor 1 (Trouble Shooting) are directed to *an*

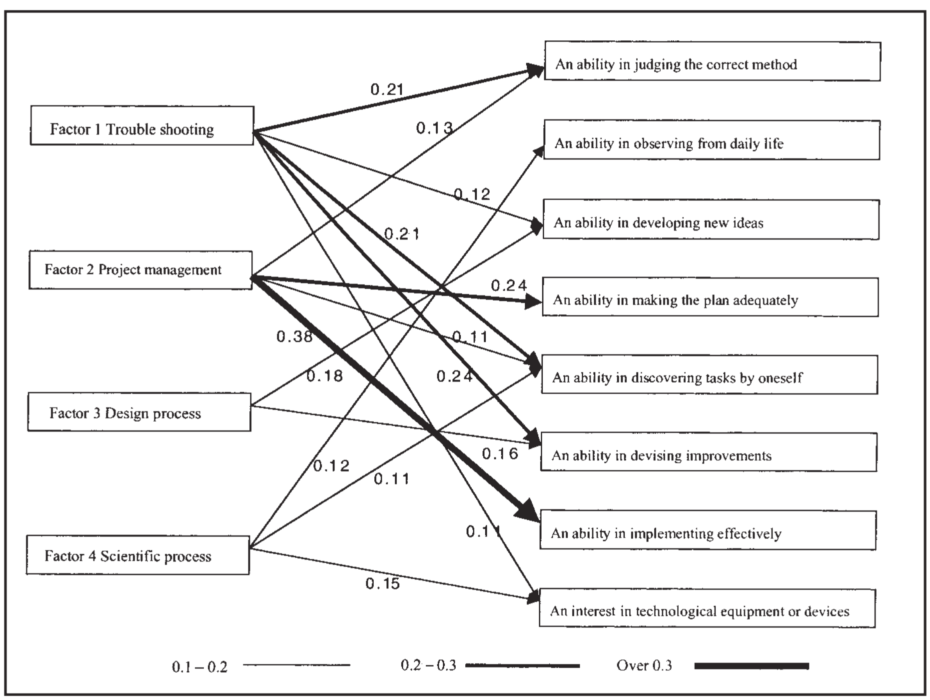

Figure 4. Path diagram between learning scenes and problem-solving abilities.

ability in judging the correct method, *an ability in discovering tasks by oneself*, and *an ability in devising improvements*. Weak paths from Factor 1 to *an ability in developing new ideas* and *an interest in technological equipment or device* were also obtained. Strong paths from Factor 2 (Project Management) to *an ability in implementing effectively* and *an ability in making the plan adequately* were obtained. Weak paths from the same factor to *an ability in judging the correct method* and *an ability in observing from daily life* were also obtained.

It is particularly obvious that students' experiences of project management and trouble shooting, which were supported by their competencies of creating criterion and intentions to reach the goal, indicated strong and wide effects on the development of abilities in discovering the task, planning, improving, and judging.

Design and scientific processes. Additionally, the results of path analyses on Factor 3 (Design Process) and Factor 4 (Scientific Process) are shown in Figure 4. The weak paths from Factor 3 (Design Process) were directed to *an ability in developing new ideas* and *an ability in devising improvements*. It is evident that students' experiences of design process, which were supported by their competencies in self-monitoring and creating criterion, indicated distinctive effects on the development of creative problem-solving abilities. There were also weak paths from Factor 4 (Scientific Process) to *an ability in observing from daily life*, *an ability in discovering tasks by oneself*, and *an interest in technological equipment or devices*. It is conjectured that scientific process, which was supported by their intentions to reach the goal, indicated the effects on development of abilities in exploring daily life from the viewpoint of technology. In previous analyses, it was suggested that scientific or analytical learning was not easy to adopt into a technological project that gives weight to manufacturing. However, this result means scientific process can give students the start points of their technological projects.

Concluding Comments

In this study, the relationships among the structure of learning activities, students' self-evaluation competencies, and problem-solving abilities in a project based approach of Japanese technology education were investigated. The main findings of the analyses are as follows:

1. Students' projects at the junior high school level were constructed from four types of learning activities: design process, scientific process, troubleshooting, and project management. However, scientific and analytical exploring of technological concepts was not significantly experienced by students in their projects.
2. It was suggested that students' projects were supported by self-evaluation competencies, especially students' strong motivation to reach their goal and generating their own criteria, contributing to their performances in trouble shooting and project management.

Table 1. Results of Factor.

Item	Rotated factor loading*				Communality	Score	
	Factor 1	Factor 2	Factor 3	Factor 4		Mean	S.D.
Trouble Shooting							
Isolate the problem	-0.60				0.45	2.70	0.96
Identify possible causes	-0.71				0.55	2.53	0.94
Implement a solution	-0.66				0.48	2.57	1.00
Test the solution	-0.63				0.51	2.31	0.96
Project Management							
Identify tasks to reach goal		0.54			0.40	2.59	0.83
Develop a plan to accomplish task in each classroom activities		0.57			0.34	2.71	0.89
Plan a sequence of procedure in each task		0.58			0.37	2.64	0.90
Implementation of the plan		0.59			0.42	2.77	0.87
Evaluation of the implementation		0.47			0.27	2.43	0.90
Modification of the plan		0.41			0.30	2.65	0.86
Design Process							
Ideation			0.68		0.51	3.05	0.95
Identify possible solutions			0.54		0.41	2.75	0.94
Final design			0.64		0.49	2.82	0.91
Brainstorming					0.23	1.95	0.97
Prototyping					0.14	1.97	1.17
Scientific Process							
Observation				0.53	0.41	2.34	0.85
Develop hypotheses				0.54	0.39	2.06	0.92
Experimentation				0.44	0.20	2.56	1.01
Draw conclusions					0.10	2.72	1.08
Eigenvalue	2.08	2.06	1.60	1.23			
Contribution	0.11	0.11	0.08	0.06			
Cumulative of contribution	0.11	0.22	0.30	0.37			

*Only loadings with values > |0.40|

3. It was suggested that the accumulation of experiences of these learning activities in students' projects promoted the development of technological problem-solving abilities related with plan-do-see. It was particularly evident that students' experiences of project management and trouble shooting have strong and wide effects on the development of the abilities of discovering the task, planning, improving, and judging. Also, design and scientific processes contributed to promoting abilities of creative problem solving and exploring daily life with a technological view, respectively.

These results show the features of the project based approach. When the aim is to develop students' technological concepts with scientific exploration, the modular approach has an advantage, as clear objectives, guided procedures, and well-prepared resources are set in place. However, this approach is not adequate for the development of the abilities of practicing plan-do-see over a period of a few months, because such an approach is designed to last for a period of 5 to 10 days. On the other hand, when the aim is to link the learning content of technology education with other disciplines, a project based approach is so specialized that learning content cannot be systematized. However, these two different approaches can be integrated into the curriculum as an interdisciplinary project. Another possible approach is the close linking of science and technology education as an alternative solution that may compensate for the absence of the project based approach.

From this viewpoint, it can be assumed that the most effective approach is the combination of various teaching-learning processes, where the disadvantages of one approach are supplemented by the advantages of other approaches. For the future, methods of combining different types of teaching-learning processes must be considered, and methodology for curriculum evaluation, from the viewpoint of promoting technological abilities, must be developed in Japan.

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References

Daugherty, M. K. (1998). *Introduction to teaching technology*, Normal, Illinois State University.

DeLuca, V. W. (1992). Survey of technology education problem solving activities. *The Technology Teacher,* **51**(5), 26–30.

Jyou, H. (1992). Structure and development stage of students' self-evaluation competencies. *Journal of Japanese Society of Technology Education*, **34**(1), 7–14. (In Japanese)

Knoll, M. (1997). The project method: Its vocational education origin and international development. *Journal of Industrial Teacher Education,* **34**(3), 59–80.

Loepp, F. L. (1999). Models of curriculum integration. *Journal of Technology Studies*, **25**(2), 21–25.

Ministry of Education, Science, Sports and Culture of Japan. (1998a). C*ourse of study for junior high schools in Japan.* Tokyo, Japan: Printing Office of Ministry of Financial Affairs. (In Japanese)

Ministry of Education, Science, Sports and Culture of Japan. (1998b). *Development of instruction for promoting students' problem-solving abilities in industrial arts and home making education—Agriculture and information basis*. Tokyo, Japan: Kaibundo. (In Japanese)

Moriyama, J., et al. (2001). A curriculum evaluation of collaborative project based on the analysis of learning activities for problem-solving in technology education. In *Annual reports of joint research of faculty of education and attached schools* (pp. 197–203). Nagano, Japan: Shinshu University. (In Japanese)

Pring, R. (1973). Curriculum integration. In R. S. Peters (Ed.), *The philosophy of education* (pp. 123–149). London: Oxford University Press.