Exploring the Problem-Solving Styles of Freshmen from a Hands-on oriented Course

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Abstract

The aim of the paper is to introduce our attempt to link the research on the human behaviors of freshman students in problem-solving from viewpoint of thinking styles to the curriculum planning for hands-on oriented courses. In order to explore the diverse problem-solving styles of the students, we conducted a research based on Sternberg's theory on thinking styles. Three types of study for cross analysis were applied: (a) observation in the classroom, (b) questionnaire and interview, and (c) experiment for problem-solving behaviors. Based on the results collected from observation and questionnaires, the complete problem-solving behaviors of the students were further observed in an experiment. Some predictions are also discussed in the paper.

Introduction

The problem-solving abilities of engineering students are very important today. The trends of curriculum development in engineering education is to offer more hands-on oriented courses in which students can learn the abstract theoretical knowledge by hands-on operation. Especially, most of the students in Taiwan have less ability in global thinking and acquire almost un-structured knowledge from the high school education. This situation is one of the difficulties while in developing course curriculum for engineering education.

Through several years of experiences in teaching creativity, design in mechanical engineering at the university, we observed a common learning difficulty to the student. Due to insufficient capability in problem-solving, students encounter setbacks in realizing their creative ideas. The setbacks depressed their ambitious creativity and even kept them from multi-facet problem solving attempt [1]. In order to overcome this hurdle, we try to investigate the correlation between thinking style and problem-solving behaviors of freshmen, so that we can devise personalized teaching strategies and learning activities not only for the fundamental but also advanced courses [2].

The study was conducted accompanying with the course "Introduction to Machines and Instruments" at the National Central University, Taiwan, which is addressed to the freshmen to offer a brief view on the development of machines and instruments. Problem-solving is also another important objective of the course. The behavioral patterns of the students in solving problems will be investigated and cataloged according to Sternberg's thinking style categories [3] so that we can identify the types associated with the most difficulties and to get inspired of relevant and effective strategies. The purpose of this paper is to illustrate our effort to improve the engineering education by exploring the correlation between the thinking styles and the problem-solving styles of the students.

Curriculum Planning of a Hands-On Course

Objectives of the course

Due to the engineering education reform ("education pull") as well as due to the needs by industry and also new development of technologies ("technology push"), the teaching objectives and the strategies of the course "Introduction to Machines and Instruments" were modified to meet the new requirements in the past years. The new objectives are derived through intensive discussion with the department faculty and also through receiving feedback from students. Acquiring the core competences of problem-solving is the first priority of the objectives to achieve in the course. One

of the corresponding developed teaching strategies is to offer hands-on oriented activities:
(a) mechatronic exercises by using Fischertechnik© kits as a platform,
(b) observation homework, and
(c) robot contest.

Hands-On Activities – Mechatronic exercises

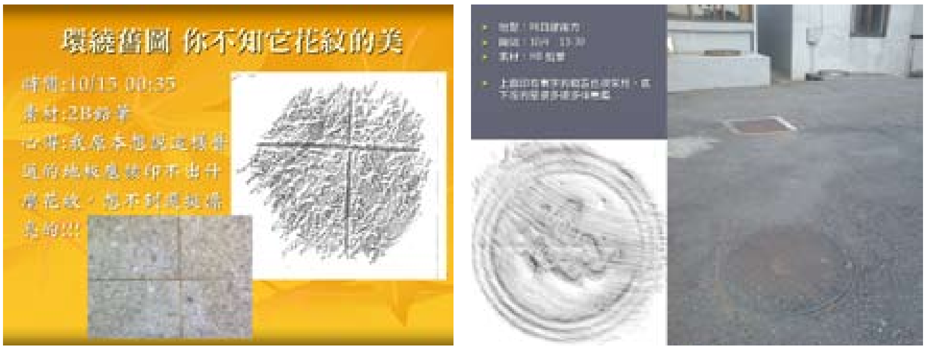
The idea to introduce the Fischertechnik© kits is our attempt to teach the students to learn problem-solving skills by facing the actual problems from mechanical design. While constructing Fischertechnik models they can not only realize their ideas by using the real building blocks, but must also solve the actual problems they encounter. The topics and the objectives of the mechatronic exercises are listed in Table 1. Each student in the exercises will learn at beginning the basic skill by constructing fundamental mechanism with Fischertechnik kits, such as linkage, gear, belt mechanisms. In the final integrated exercises, the students will learn how to build mechanisms to meet the specific requirements of motion and function. The ability to integrate domain knowledge to solve mechatronic problems can be also acquired. For example, the students must construct a car with infra-read remote control (see Figure 1).

Figure 1. Fischertechnik Kit used in the course (left); Remote controlled car (right)

Table1. Topics and corresponding objectives of mechatronic exercise

No.	Topics	Objectives
0	Fundamentals on Fischertechnik Modules	To learn the experience and the skill how to use FT-Modules to construct mechanism
1	Linkage Mechanism	To learn and verify Grashof's Law through construction of mechanism
2	Various Mechanisms	To learn basic structure and motion type of cam, chain, belt and gear mechanism; and how to apply them to the specific problem for power transmission
3	Electric Control Modules	To learn how to use the different types of sensors and the flip-flop controller to solve the problem of motion control
4	Various Engines	To learn how the air engine, the steam engine, and the Stirling engine work
5	Steamboat	To learn how to control machines by using programming software
6	Programming software -- ROBOPro	To learn how to control machines by using programming software
7	Integrated Exercise: Walking Machine	To build a machine that can walk without aid of any wheel
8	Integrated Exercise: RF-Remote Controlled Car	To build a car that can run along a defined route through RF-remote controller
9	Integrated Exercise: Tracing robot	To build a car that can run in a specific path by tracing

Figure 2. Two rubbing articles from the campus



Hands-on homework – Observation

The students acquire another core competency for problem-solving, i.e. observation. As assigned in the hands-on homework, that they should find out and observe some articles in the campus and make rubbings of them. Two slides with the rubbings and the corresponding description about the articles are shown in Figure 2. With comparison of the actual objects and the rubbings the students can have totally different experience on observation, as we expect.

Contests

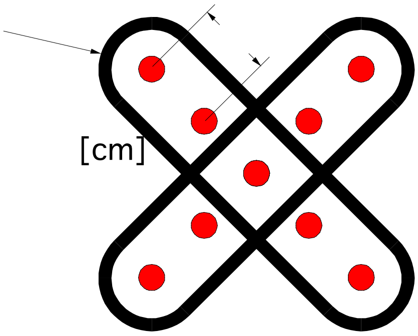
A contest can (a) motivate the students, (b) impart a good sense of reality, (c) train to work in simulated but realistic industry-like settings of limited resources, time pressure, and high competitiveness, and (d) teach the importance of co-operation and teamwork [4]. Based on these arguments we hold therefore two contests in the course: the steamboat contest and the robot contest.

<u>Steamboat contest.</u> At the middle of the semester, the students must use an 1/8" copper pipe in the length of ca. 40 cm, a tea light and any material found in everyday things to construct a steamboat with the highest speed. It is not difficult to build a steamboat, but it is indeed not easy to obtain a rapid and stable one. Students must find out difficulties and even solve problems. A steamboat made by a participant is shown in Figure 3.

<u>Robot contest</u> is held at the last weak of the semester. In order to motivate the students, the theme and the rules of the contest were discussed and specified by the students themselves. For example, the contest task in the academic year 2008 is to build three different types of robot to fulfill the requirements of each sub-task respectively. For example, they should build a tracing robot car which can move following the black path and also puncture the paper over the five cans, Figure 4.

Figure 3 Steamboat for the contest

Figure 4 Task for the robot-contest: 3rd sub-task and a tracing robot



Necessity of study on human behaviors in problem-solving

Although the proposed course with many hands-on learning activities is very attractive to the freshmen each year, an improvement of curriculum is restricted due to diverse difficulties generated by individual students. It is thus necessary to explore the human behaviors of students in problem-solving, so as to obtain a set of suitable teaching strategies.

Thinking Style and Problem-solving Styles

Sternberg's theory of mental self-government on the thinking styles

Sternberg classified 13 different thinking styles according to the categories function, form, level, scope and leaning based on the theory of mental self-government. The brief outline on the Sternberg's thinking styles are listed in Table 2, more details see [3].

Prediction of the designer's behaviours based on the thinking styles

Based on the research on the problem-solving characteristics of novices [5, 6, 7], we might expect how the freshmen having different thinking styles solve their problems in the following ways:

<u>Problem-solving strategies.</u> In general legislative students like to create their own rules and have thus a tendency of creative thinking. However, they may not solve a complicate problem effectively, when they have not enough knowledge for solving or analyzing the problem. In contrast to legislative, freshmen with executive style desire to follow the existing and structured rules, and have therefore the sufficient knowledge to solve problems. Of course they lack motivation to apply creativity to solve some problems with ambiguous conditions. Designers with judicial style prefer to analyze and evaluate creative ideas in a design team. They can give good suggestions for task in a team.

<u>Problem-solving stages.</u> Legislative people will invest more time in searching their own solutions, while executive people in clarifying the task and searching suitable methods. Judicial people spend, on the other hand, more time in evaluating and testing their solutions.

<u>Frequency of transient to different stages.</u> Most people with hierarchic style can solve problems systematically. Monarchic designers tend to focus on the thing or the problem that they are dealing with. They may also solve problems creatively. It is not suitable, however, to assign oligarchic designers to solve a complicate and ambiguous problem, because they can not decide the priorities of the objectives of the task. The designers with anarchic style are perhaps the worst to formulate and understand the task or the problem, but they can also do their best by trial and error.

<u>Problem-solving quality.</u> Because people with conservative style tend to solve problems following the existing rules or the past experience, conventional solutions are expected to be found. On the other hand, the liberal people

can give more innovative solutions for ambiguous problems.

Table 2. Categories of thinking styles

Categories	**Functions**	**Forms**	**Levels**	**Scopes**	**Leanings**
Styles	*Legislative* *Executive* *Judicial*	*Monarchic* *Hierarchic* *Oligarchic* *Anarchic*	*Global* *Local*	*Internal* *External*	*Liberal* *Conservative*

<u>Handling resources.</u> The external thinking people tend to integrate the ideas or concepts of other people into their solution. People with an internal style, on the other hand, perform as introverted and are persistent to change their ideas.

<u>Global and local thinking.</u> People with global style can analyze the problem with an overall view and give suitable and effective solving strategies. However, an ideal problem solving behavior also needs the local thinking style to take care of the details of conceptualizing and implementing.

Cross Analysis

In order to explore the diverse problem-solving styles of the students, we conducted a research based on Sternberg's theory on thinking styles. In our research three types of study for cross analysis were applied: (a) observation in the classroom, (b) questionnaire and interview, and (c) experiment for problem-solving behavior. Based on the results collected from observation and questionnaires, the complete problem-solving behaviors of the students were further observed in an experiment.

Observation in the Classroom

We observed some students having significant thinking styles at the Fischertechnik-exercises to explore the problem-solving behaviors of students during constructing the machines. The observation lasted for 45 hours (3 hours per week), whereby the behaviors were recorded not only in a note on-site but also by using video-recording and photograph.

Questionnaire and Interview

Each student in the course has written a thinking styles questionnaire adopted from Sternberg [3]. In order to have more reliable analysis results, two half-structured interviews, each at the begin and at the end of the semester respectively, were also conducted to gather more information about the responses of students to their problem-solving process and the questionnaires.

Experiment for Exploration of Problem-solving Behavior

An experiment was conducted to explore the relation between the problem-solving behaviors and the thinking styles of freshmen. The subjects were requested to construct a vehicle by using the Fischertechnik kit to meet the requirements that the vehicle must go through three obstacles, i.e. a rugged field, a stair with five steps and a slope. See Figure 5(a). The complete problem-solving behaviors from the begin to the end were not only observed by the observers on-site but also recorded by video cameras. Figure 5(b) shows the arrangement of the experiment. Each student had a box of Fishertechnik modules and about 4 hours to construct her/his ideal vehicle that can overcome the specified problem. Figure 6 shows the experimental process of one experiment and a result of the vehicles constructed by the subjects.

Figure 1 Test field and arrangement of experiment

(a) (b)

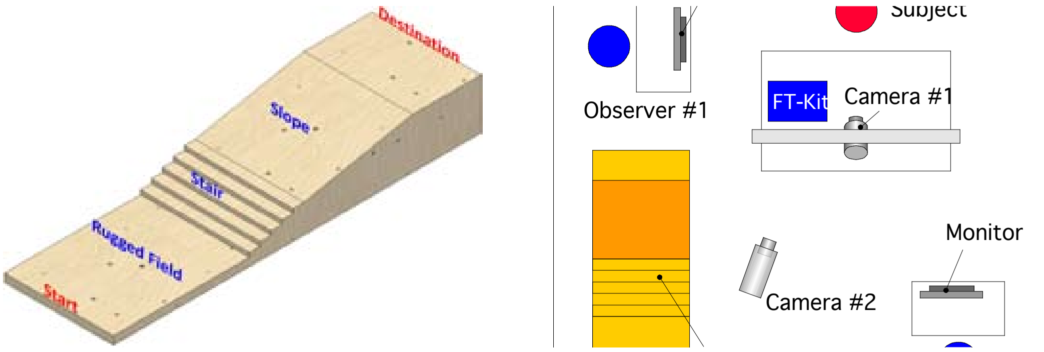
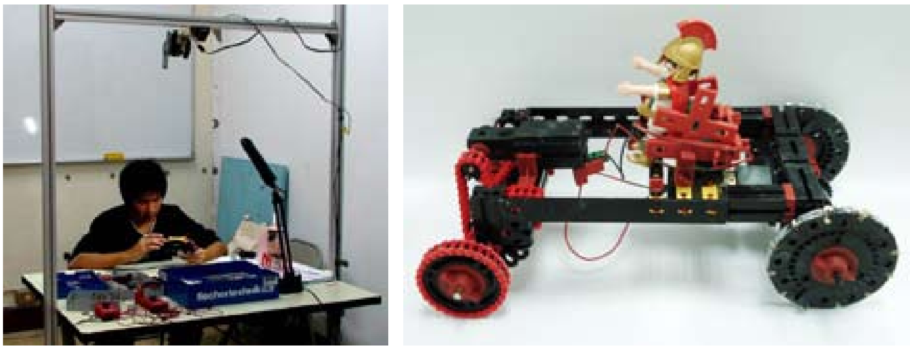


Figure 2 Experiment and one result of a studen



Conclusion and Future Works

This paper illustrates our attempt for linking the research on the problem-solving behaviors from the viewpoint of thinking styles to the development of teaching strategies. Through three types of cross analysis, observation in the classroom, questionnaire/ interview, and experiment for problem-solving behavior we are expecting to explore the correlation between of problem-solving styles and thinking styles, whereby the learning difficulties of students with diverse thinking styles can be found out for further curriculum planning.

Since the study is still on-going, and the results are not involved in the paper, but some predictions are also discussed. Those concepts will be suitable for further development of teaching strategies for course improvement.

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