# Remarks on Education Method to Turn Failure Experience to Instructions for Engineering Design

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## Abstract

This article proposes to examine how the study of failure differs from other technical subjects, and how to turn failure experiences to one's advantage. The authors surveyed the properties of failures in PBL (Project Based Learning) and also examined students' interest and understanding of failure, after introducing failure examples. To investigate how students communicate failure experiences to third parties, reports of the failure experience in PBL were evaluated. From abovementioned surveys, we get the following results. The typical causes of failurein educational institutions are lack of skill in manufacturing and inadequate planning, which conversely are minor causes of failure in the industry. A knowledge database on failure, employed commonly in industry, is not effective in PBL, because projectsin educational institutes are usually changed every year. Case studies in failure can be approached from many points of view including causes, processes, effects and safety measures. While teachers should emphasize the notable points in the failure examples in introducing examples of specific topics in machine design, teachers should explain the multiple aspects in the failure examples to educate students about the complexity of actual accidents.

**Keywords:** Engineering Education, Study of Failure, Education Technique, Machine Design

## Ⅰ. Introduction

People can understand causes, processes and results of failure after an accident occurs, but we are often unaware of them before trouble appears. As failure involves human actions, prepared exercises arenot always educationally suitable. Furthermore, technological information on failure is often not reported. Because of these characteristics of failure, we need to introduce a different scheme from conventional technical subjects in educational institutions. In industry, a knowledge database of failure, for example, has been utilized. In education institutions, teachers have attempted to simply introduce a database to avoid careless failure in classes. In this paper, we propose using educational methods to turn experiences of failure into instructions for engineering design.

The authors surveyed the properties of failures in PBL (Project Based Learning) and the views of students, teachers and managers of design divisions in companies [1]. After being presented with examples of failure, the authors also examined students'interest and understanding of failure by questionnaire [2]. On the basis of the previous research, reports of the failure experience in PBL are evaluated to investigate how students communicate failure experiences to third parties.

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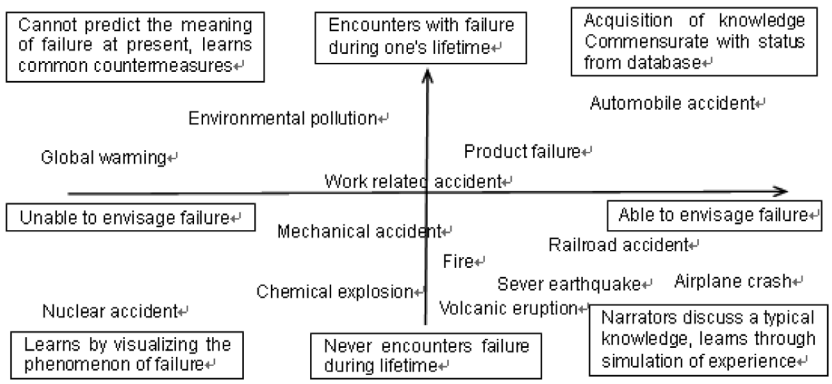
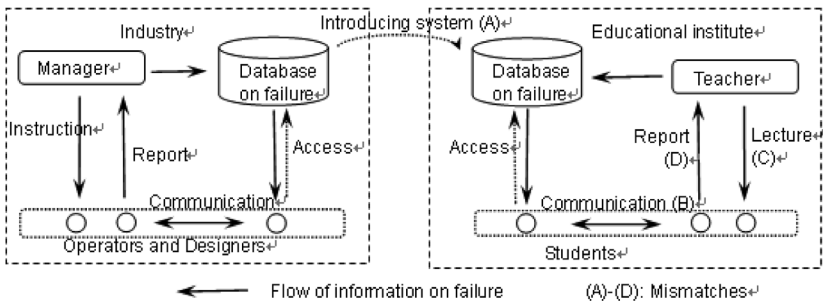
## Ⅱ. Methods of using Knowledge of Failure

[Fig. 1] shows the schematic diagram, 'methods of using knowledge of failure'proposed by the failure study research group [3] of the University of Tokyo. The approach using a database, which is employed in industry, is in the upper right quadrant. The proposed idea can be used to determine which education method should be employed in educational institutes. In that case, differences and mismatches mentioned later should be taken into account; that is, the location of each failure in [Fig. 1] depends on individual perspectives.




[Fig. 1] Methods of using knowledge of failure (modifying idea by Nakao et al., 2003).




[Fig. 2] Flow of information on failure in industry and educational institute

## Ⅲ. Differences and Mismatches to Failure

People understand and manage failure through their experiences, hence rarely noticed differences and mismatches of failure appear in people's understanding and actions. These mismatches, which make the study of failure difficult, are summarized in the following sections:

### 1. Differences between failures in class of PBL and those in industry

(1) One of most popular way to avoid failure in industry is to use a knowledge database on failure. Since production processes are routinized, workers can focus on operations or design processes. Students, however are interested in failure directly related to the topics, therefore, few students access the database for old example of failure in PBL, if the topic of PBL is changed. The knowledge databases of failure in educational institutes are effective for subjects such as conventional laboratory or practice on machine work, for safety education (see (A) in [Fig. 2]).

(2) Since students have scant manufacturing experience, they tentatively manufacture a prototype without adequate design, and then try to succeed by trial and error. It is extremely difficult to succeed when planning is inadequate. To avoid failure in the planning, the presentation of concrete design and pre-tests to confirm the adequacy of the designs should be required.

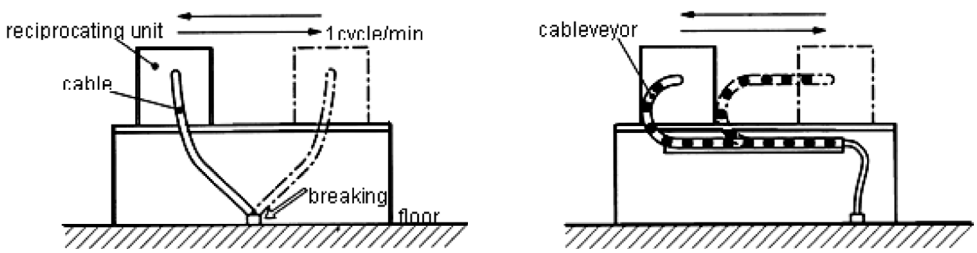
(3) Results of questions to 78 fourth year students; ‘what are the two most important factors to avoid failure’ and ‘what are the two biggest weakness in your abilities’ are summarized in <Table 1>. One of major failure causes in industry is poor communication, but students think that they have sufficient abilities and skills of communication. This is because students have not experienced complicated production processes involving many people (see (B) in [Fig. 2]).

### 2. Mismatch of interest in failure example introduced by the teacher (see(C) in [Fig. 2])

(1) After being shown failure examples, many students naturally think that the most important factor for avoiding failure is to survey and collect failure

<Table 1> Change of students' idea before and after introducing failure examples.

| Factors (Student could select two) | Percentage of Student (%) (important factors) | | Percentage of Student (%) (weakness of one's ability) | |
|---|---|---|---|---|
| | Before | After | Before | After |
| To study specific subjects | 21 | 15 | 41 | 35 |
| To study broad range of subjects | 25 | 29 | 27 | 27 |
| To survey and collect failure information | 33 | **48** | 41 | 41 |
| Cooperation and Communication | 29 | 25 | 12 | 12 |
| Concern for failure and careful action | **40** | 44 | 27 | 27 |
| Failure experience in practice | 35 | 24 | **43** | **43** |




(a) breaking wire by local bending (b) cable protected from local bending

[Fig. 3] Breaking wire of reciprocating unit [4].

information. However, the percentage of students who focus on specific subjects decrease (see <Table 1>). Students' understanding about failure is direct and superficial, and teachers seldom notice the change of students' attitude toward failure. To understand failure causes and safety measures, knowledge of technical subjects is required.

(2) Failure has multiple aspects, therefore people are interested in a variety of points after introducing failure examples. To avoid confusion, the teacher should introduce failure example in the following manner:

(a) Teachers should emphasize the notable points in the failure examples in introducing examples of specific topics in machine design. If teacher introduce failure as a material of the lecture, students can understand the actual case related to the topics in class.

(b) Teachers should explain multiple aspects, in the failure examples to educate students about the complexity of actual accidents.

**Example of various instructions from failure**

After introducing the breaking-wire accident of a reciprocating unit that had been operating continuously for a period of 24 hours (see [Fig. 3]), we surveyed students'interest and understanding.

Lessons learned from the failure example (the percentage of students) are listed as follows:

(a) Design using materials with different external and internal components (copper wires are covered by plastic) (20%)

(b) Fatigue failure induced by 'slow' iterative bending (no high frequency) (15%)

(c) Matter of mechanism in which a cable is bent locally (35%)

(d) Required general knowledge of the related fields (in the explanation of failure, the following is mentioned; to avoid local bending of cables is 'general knowledge' for engineers handling the wiring of robots) (15%)

In this case, 35% ((a) and (b)) and 50% ((c) and (d)) of students remarked on the material and the mechanism, respectively. On the other hand, most teachers are interested in the mechanism to avoid local bending. Students are apt to be attracted to human factors such as what and how people think when failure occurs.

## 3. Mismatch of failure experience

reported by students (see (D) in [Fig. 2])

In general, while teachers know more than students

and find their mistakes frequently,teachers are apt to regard unfamiliar information from students as a mistake. Furthermore, the technical background of failure is not explained in student's reports. To avoid such mismatches teachers should check unfamiliar information, if it comes from multiple students.

Example of unfamiliar information from students to teacher.

We planned a time trial of paper vehicles with a rider, as the class of PBL. After the class, to survey how the failure information had been spread to others, teachers and graduate students evaluated reports where students were required to analyze the failure experiences. Some students pointed to the anisotropy of the paper, but their experience was underestimated by teachers and graduate students. In the process of papermaking, fibers of a paper are oriented in the tension direction, the so-called machine direction. Through experience only, students understand that curling, bending and folding properties of papers are anisotropic, however they cannot link their experiences to theory.

## Ⅳ. Discussions

Surveying accidents only, leads students to memorizing failure examples. Even if we employ a large database, it can never be complete, but we can list the possible causes of failure. Therefore, training to predict failure (to think what would happen in the next step) is helpful to avoid failure. The ability to envisage failure can be taught, so the location of each failure in [Fig. 1] can be translated to the right. If students learn to envisage failure, they can use a database effectively, because of the wide region of the upper right quadrant. Risk assessment is one of the good practices for thinking about failure. In practices of risk assessment, learners survey processes, list risk factors, estimate level of risks, evaluate permissible risk and assess safety measures.

## Ⅴ. Conclusions

In educating students about failure studies for instructions of machine design, we found several differences and mismatches as follows: 1) difference between failures in PBL classes and those in industry, 2) mismatch of interest in failure example introduced by the teacher, 3) mismatch of failure experience reported by students.

Difficult points to communicate failure with others are that these differences and mismatches are rarely noticed.

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