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Improvements in Teaching Projection Theory Using Failure Mode and Effects Analysis (FMEA)

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Abstract: One of the most important courses in engineering curriculum is "engineering drawing". In fact, engineering drawing is the language of conversation and realization between engineers. This course consists of 3 parts: projection theory, basic drawing and mechanical drawing. The most important part between these is projection theory because it supports one of human intelligences named "spatial ability" that is vital for an engineer. Otherwise, time limits, increasing of user demands and need to higher reliability, causes us to think about "problem prevention" instead of "problem solving". The tool helps us in this way is "failure mode and effects analysis" or FMEA. In this study, after description of FMEA elements and method of its implementation, apply it on education of projection theory in engineering drawing course and detect and analyze failure modes and effects of them, then find solutions and recommendations to prevent or weaken of these effects and finally represent result as properties of appropriate teaching of projection theory.

Key words: FMEA, projection theory, spatial ability, RPN, analyze

INTRODUCTION

Engineering drawing is one of the most important courses in engineering curriculum. Often, this course is compulsory in engineering universities. The aim of it is to achieve skill of drawing and reading technical drawings that is common language between engineers. Content of this course is consist of: projection theory, basic drawing and mechanical drawing and between these 3 parts projection theory which is the base of other parts has special importance (Zuo *et al*., 2003). One of the significant applications of projection theory is reinforcement of "spatial ability". Spatial ability is one of 7 human intelligences and each person must link his/her present knowledge to previous knowledge by one of these 7 intelligences to develop correct and immanent perception in his/her mind. Other intelligences are linguistics, logical, bodily kinesthetic, musical, inter-personal and intra-personal (Garcia *et al*., 2007). Spatial intelligence consists of spatial-mechanical techniques and is base of becoming skillful in 3D, volume and space-time, so it is the most important intelligence for an engineer and its amplification and expansion is necessary.

The other applications of projection theory are expansion of invention and creativity, sympathy to continue engineering curriculum, familiarize with some industrial parts and their imagination and becoming skillful in problem solving.

As you now, we can bobble in doing things. An ancient mountaineering adage says: "anything can possibly go wrong, does" (Carlson, 2012) so, we can say all processes amongst teaching engineering drawing and specially teaching projection theory can has errors which need to prevented or discounted before effect on end users (students).

Otherwise, at the present time, the time is limited, demands of users increased and higher levels of reliability needed. Before, trial and error was adequate method to improve processes but nowadays, this method is very time consuming and expensive. That's why, it is necessary to concentrate on preventing failures instead of solve problems, hence, we should forecast factors which can cause failure and become sure from robustness of our design. The mean can helps us in this method is "failure mode and effects analysis" or FMEA (Carlson, 2012).

In this study, first we describe FMEA elements and its implementation and then apply it on teaching of projection theory in engineering drawing course, anticipate blind spots and failure modes, their effects and causes and finally represent solutions for eliminate or discount them and as a result enumerate properties of successful teaching of projection theory.

FMEA AT A GLANCE

Brief history of FMEA: First use of FMEA regards to 1949 by US military in form of standard named "procedure document MIL-P-1629" and titled "Procedure for Performing a Failure Mode Effect and Critically Analysis". Aim of this text was assortment of failure modes based on their effects on success of mission and safety of equipment and personal.

In 1960s, FMEA used in travel of mankind to the moon and his safe returning. In 1970s, Ford Company by

goal of increasing reliability of produced motors applies FMEA. In 1980s, automotive industry standardized FMEA to wide use of it in designs and processes (Carlson, 2012).

However, primarily FMEA only used for special military purposes, today, it has capability of use in wide range of industrial and service applications.

Definition of FMEA and its purpose: Word FMEA is first letters of "failure mode and effects analysis" and is a method to identify potential failure modes, their causes and effects on system or end user for a product or process. It determines risk of failure modes and actions for betterment of designs and procedures and defines corrective actions for higher risk priorities and their implementations.

FMEA is an engineering method which purpose is to find and correct failure modes before achieving the product to end user and is a mean that applies as a guide to implement a series of actions in order to decrease risk priority of a process to a reasonable level.

FMEA elements and procedure of its implementation: To implement a FMEA process we need a multi-skill team and we complete a worksheet such as Fig. 1. Definition of FMEA elements and method of completing worksheet are as following.

Item: It is the name of component or step of process which is analyzing.

Function: It is to doing special action on special thing by special mean to achieve an identified goal and consists of principle functions, additional functions, dependent functions, preventive functions and defending functions.

Failure mode: It is a manner which one item or function may potentially does not do its duty or do it faulty.

Effect: It is result of a failure mode on whole system or end user which based on type of it can has different levels. For example, it can only effecton self-process and related functions or can effect on some higher level functions or end user. Often there is more than one effect for a failure mode but mostly we should pay attention to the most intensive effect.

Severity: It is a ranking number which is related to the most intensive effect of a failure mode and is determined based on scale and range of analyzing FMEA. This number is not depend on other numbers such as occurrence and detection. An instance of FMEA severity (Table 1).

Cause: It is special reason for a failure mode and determined by using word "why" until main root reason become founded. By definition when a cause occurs its failure mode occurs too. We can recognize several causes for a failure mode.

Occurrence: It is a ranking number which is related to likelihood of a failure mode and its causes and defines based on order and scale of analyzing FMEA. This is an independent number and has no relation with other numbers such as severity and detection.

Controls: These are procedures or actions which prepared to eliminate or discount risk priority of each cause. They can be in type of preventive controls or detective controls. Mostly preventive controls determine occurrence number. An instance of occurrence shown in Table 2. For a single cause we can determine several controls.

Table 1: Severity table (Chang and Sun, 2009)

Ranks	Effects
10	Hazardous
9	Serious
8	Extreme
7	Major
6	Significant
5	Moderate
4	Low
3	Minor
2	Very minor
1	None

Table 2: Occurrence table (Chang and Sun, 2009)

Ranks	Probability of failure
10	Extremely high
9	Very high
8	Repeated failure
7	High
6	Moderately high
5	Moderate
4	Relatively low
3	Low
2	Remote
1	Nearly impossible

Item	Function	Potential failure mode	Potential effects of failure	Severity	Potential causes of failure	Occurrence	Preventive controls	Detective controls	Detection	RPN	Recommended action	After recommended action			
												Severity	Occurrence	Detection	RPN

Fig. 1: Generic FMEA worksheet (Saipa, 2005)

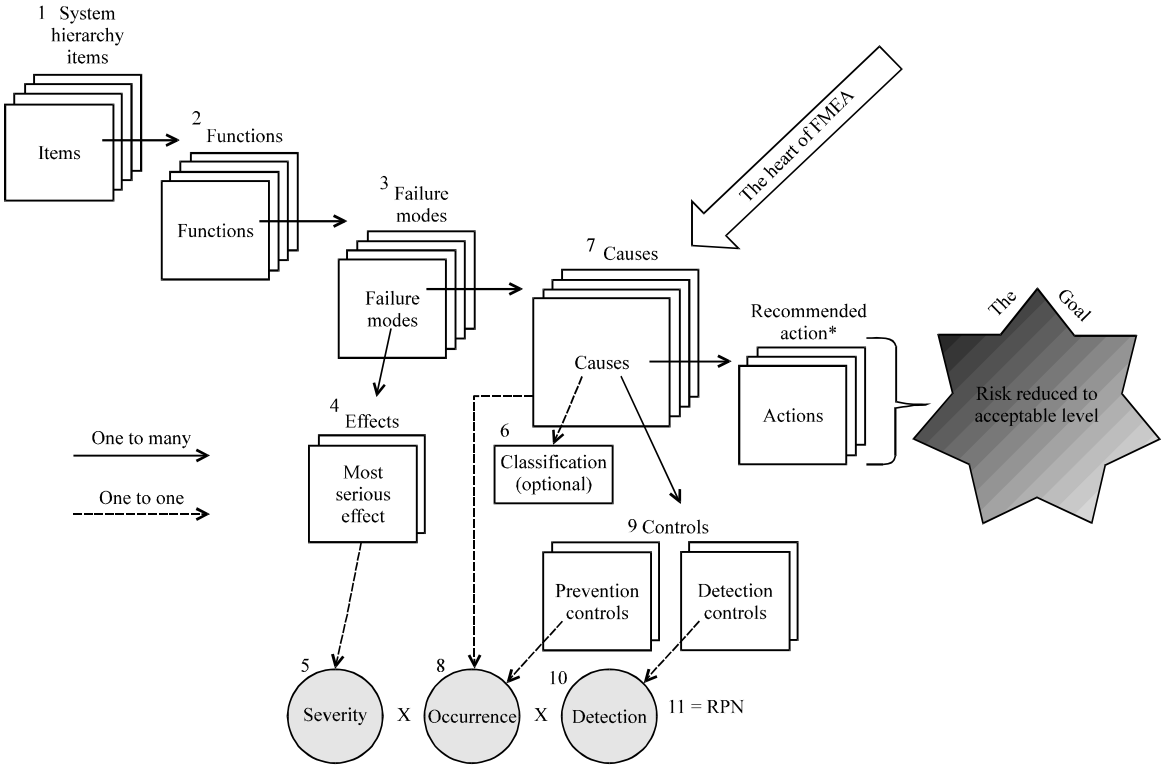

Fig. 2: Logical relationship between FMEA elements (Carlson, 2012)

Table 3: Detection table (Kolich, 2014)

Ranks	Detection rate
10	Absolute uncertainty
9	Very remote
8	Remote
7	Very low
6	Low
5	Moderate
4	Moderately high
3	High
2	Very high
1	Almost certain

Detection: It is a ranking number which is related to the best control between detective controls based on scale and order of analyzing FMEA. This number determines likelihood of detect of a failure mode or its cause before it occurs. Detection number is only related to FMEA scope and has no relation with other numbers such as severity and occurrence. Table 3 shows an example of detection.

RPN: It is first letter of "risk priority number" and in fact is a ranking number for risk of each failure mode/cause and obtained from the following product:

RPN = (Severity of the effect)×(Likelihood of occurrence of the cause)×(Likelihood of detection of the cause)

Recommended actions: These are operations which suggested to after its implementation Risk Priority Number (RPN) decreases. Additionally, in finding these actions should pay attention to current controls, relative importance and cost of corrective action. For each cause, we can define several recommended actions.

After implementing recommended actions we can calculate RPN again and for adequate actions this RPN must decreases. Figure 2 shows logical relationship between FMEA elements. Causes are the heart of an FMEA and risk reduction is the goal of it.

COLLECTING INFORMATION

The most important role of multi-skill team is to collect information about the process. Also, all things which risk potential concealed in them such as devices, mankind, material, environment, method, etc. should be checked accurately.

Precise and useful information can be obtained from interview with experts and end users (students in this case), checking devices and new methods, articles, books, results of assessment of teacher and method of teaching by students, brainstorming, internet, etc.

After it we should prepare a list of process steps, its items and then failure modes and analyze causes precisely by use of above resources. Next action is to identify risk of each cause by assist of experts and refer to tables and

Table 4: FMEA implementation for teaching projection theory

Items	Function	Potential failure mode	Potential effects of failure	Severity	Potential causes of failure	Occurrence	Preventive controls	Detective controls	Detection	RPN	Recommended action	After recommended action			
												Severity	Occurrence	Detection	RPN
Projection theory	Education of spatial ability	Faulty and incorrect perception of spatial ability	Low imagination and visualization power	10	Disability of teacher in explanation and inadequate method (Gurney, 2007)	6	Employment of teachers with sufficient knowledge, dominant in teaching and good public relations (Gurney, 2007)	Control of assessment scores of teachers at the end of semester	4	240 200 240	Assessment of teacher and method at 3rd or 4rd session of class	10 10 10	6 5 6	3 3 3	180 150 180
			Weakness in perception of objects relations		Insufficient knowledge of teacher (Gurney, 2007)	5									
			Weakness in communication with previous education		Unsuitable relations between teacher and student (Gurney, 2007)	6									
			Creation of weak base for future education		Unclear shapes and examples while teaching	8	Use of presentation and animation software's to transfer more information	Conversation with students	7	560 490	Having a software so can rotate objects and see their details and transfer lots of information in little time (Zuo *et al*., 2003)	10 10	4 4	7 7	280 280
					Transferring low information because of only use of blackboard and chalk	7									
	Forgetting some educated things of spatial ability		Creation of weak base for future education	9	Lack or weakness of a consistency system after class	5	Giving homework to students	Assessment of homework	3	135	Consistency of education by network Possibility of follow up matters in internet by students Having a workbook with multimedia CD such as a teacher (Zuo *et al*., 2003)	9	3	3	81
Projection theory	Education of some method of descriptive geometry	Faulty and incorrect perception of descriptive geometry	Only use of imagination by student	7	Disability of teacher in explanation and inadequate method (Gurney, 2007)	6	Employment of teachers with sufficient knowledge, dominant in teaching and good public relations (Gurney, 2007)	Control of assessment scores of teachers at the end of semester	4	168 140 168	Assessment of teacher and method at 3rd or 4th session of class	7 7 7	6 5 6	3 3 3	126 105 126
					Insufficient knowledge of teacher (Gurney, 2007)	5									
					Unsuitable relations between teacher and student (Gurney, 2007)	6									
					Unclear shapes and examples while teaching	8	Use of presentation and animation software's to transfer more information	Conversation with students in class	7	392 343	Having a software so can rotate objects and see their details and transfer lots of information in little time (Zuo *et al*., 2003)	7 7	4 4	7 7	196 196
					Transferrings low information because of only use of blackboard and chalk	7									
		Forgetting some educated things of descriptive geometry	Only use of imagination by student	7 7	Lack or weakness of a consistency system after class	5	Giving homework to students	Assessment of homework	3	105	Consistency of education by network Possibility of follow up matters in internet by students Having a workbook with multimedia CD such as a teacher (Zuo *et al*., 2003)	7	3	3	63

Table 4: Continue

Items	Function	Potential failure mode	Potential effects of failure	Severity	Potential causes of failure	Occurrence	Preventive controls	Detective controls	Detection	RPN	Recommended action	After recommended action: Severity	Occurrence	Detection	RPN
Projection theory	Actuation of students creativity	Do not actuate students creativity by students	Lack of presenting inventive solutions 6	6	Homework's and projects are monotone and have only one answer (Dym *et al*., 2005)	9	Revision of homework's each semester	Assessment of homework	3	162	Giving projects which need creativity Assessment of concept instead of exact final solution (Dym *et al*., 2005)	6	5	2	60
					Long lecture time	8	Association of students in class discussions	Control of assessment scores of teachers at the end of semester	4	192	Use of bright students in codification of homework's Use of computer and multimedia in teaching so lecture time lowers	6	5	4	120
						8									
					Teacher has low level of creativity and pry (Gurney, 2007)	7	Employing teachers with creativity			168	Assessment of teacher and method at 3rd or 4th session of class	6	5	4	120
					Separation of design and technical drawing (Dym *et al*., 2005)	8	Revision of homework's and lectures each semester	Assessment of homework	3	144	Giving projects which related to updated industrial problems and student should test several solutions and learn things in higher level	6	5	2	60
Projection theory	Making interest for students to continue learning	Not to make interest for students to continue learning	Leave learning and faulty education Having passive students instead of active ones (Yang, 2013) Not to associate students in class discussions	6	Unabsorbing shapes because of only use of blackboard and chalk	7	Use of more absorbing shapes in lecture	Assessment of homework	3	126	Use of computer, 3D software and multimedia with ability of rotating objects (Zuo *et al*., 2003)	6	4	3	72
					Long lecture time because of only use of blackboard and chalk	7	Association of students in class discussions	Control of assessment scores of teachers at the end of semester	4	168	Use of computer and multimedia in teaching so lecture time lowers	6	4	4	96
					Weak relation between teacher and student (Gurney, 2007)	6	Employment of teachers with good public relations (Gurney, 2007)			144	Assessment of teacher and method at 3rd or 4th session of class	6	5	4	120
	Familiarize with some industrial shapes and their imagination	Not to familiarize with industrial shapes and their imagination	Creation of weak base for future education Low efficiency of students in practical works Not to familiarize with engineering design process	7	Use of abstract shapes in education	8	Revision of lectures each semester	Control of assessment scores of teachers at the end of semester	4	224	Use of examples and homework's with industrial shapes	7	5	4	140
					Use of abstract shapes in homework's	8	Revision of homework's each semester			224		7	5	4	140
					Teacher has low level industrial knowledge	7	Employment of teachers with good industrial knowledge			196	Implementing visits from industrial centers	7	5	4	140
Projection Theory	Creating skill of problem solving in students	Students have no or weak ability of problem solving	Disability of students in exams Disability of students in solving homework's Disability to solve work problems in future Creation of weak base for future education	8	Not to see steps of problem solving because of only use of computers in learning	8	Use of blackboard and chalk to show solving steps	Assessment of students homework's	3	192	Use of computer and chalk and blackboard simultaneously so lecture time lowers, rate of information transfer increases in limited time and steps of problem solving seen (Zuo *et al*., 2003)	8	4	3	96
					Nonchalance in solving problems by students	8	Explanation of importance of lesson at the start of each session		3	192		8	4	3	96
					Weakness in other items	7	Effective learning of other items			168	-	8	7	3	168

references. For more precise identification of risk numbers attention to documents, standards and needs of process are very useful.

APPLYING FMEA ON TEACHING PROJECTION THEORY

FMEA worksheet completed for teaching projection theory and failure mode and effects analysis performed on it (Table 4).

CONCLUSION

FMEA is a systematic engineering method which first find potential errors and then by representing solutions solve or discount them. Therefore, we can say by implementing FMEA and repeating it in particular periods we can achieve to a type of "continuous improvement". However, FMEA is an engineering method but it can be used in other areas to economize time and cost and increase reliability. By knowing importance of teaching of projection theory and applying FMEA on it, we can represent the following items as properties of successful teaching of this section of engineering drawing course.

Use of more interesting shapes and matters by computer methods, multimedia and soft wares which have capability of rotation and visiting object elements and simultaneously applying chalk and blackboard so steps of solving clearly become observed.

Revision of lectures and exercises at the end of each semester, giving exercises as homework to students, correction, assessment and analyzing feedback of them, associating students in class discussions, giving projects which are combination of design and engineering drawing, representing industrial examples and keeping away from abstract ones, making visits from industrial centers, associating bright students in codification of home works and projects, assessment of home works, projects and exams based on concepts and avoid from single and exact answer problems, following up education by network and internet and representing a workbook with CD in form of multimedia such as a teacher.

Employing teachers with sufficient knowledge, dominant on teaching method, energetic, having good relation with students, creative and with industrial history. Assessment of teacher and teaching method once at 3rd or 4th session of class and once at the end of semester to avoid or discount probable errors, question and answer with students, keeping away from long lecture time and expressing importance of each session at the start of it.

By implementing above actions, however, we cannot maintain that all errors and failure modes identified and eliminated but paying attention to decreasing RPN, we can say potential critical failure modes and their causes mostly identified and discounted.

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