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Proceeding of the 11th International Conference on Developing Real-Life Learning Experiences : Learning Innovation for ASEAN

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Developing Real-Life Learning Experiences: Learning Innovation for ASEAN

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Faculty of Industrial Education
King Mongkut's Institute of Technology
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TABLE OF CONTENTS

Parallel Session 1D: Room 704

10.20– 12.20	**Chairs: Ajarn Atitunch Pin-ngern and Ajarn Piyanuch Trisattayanmuni**
10.20 -10.40	Improving Problem-Solving Skills for Undergraduate Mechanical Technology: A Case Study of Mechanical System Modeling *Dr. Weerayute Sudsomboon*
10.40 -11.00	Comparison of Achievement Between Two Teaching Method on Subject Maintenance of AC Motors: Confrontation Group Study and Confrontation Group Study in combination with Network Online Study *Mr. Komkrit Klinsresuk*
11.00 -11.20	The Developing Problem-Based Model on Electrical Circuit 2 and Device Subject *Ms. Thitiya Sanguanwong*
11.20 -11.40	Embedding Learning and Problem-Solving Skills in General Education : Course Design and Student Learning Attitudes *Ms. Chantima Pathamathamakul*
11.40 -12.00	Factors Affecting Competency in Air Conditioner Job Training of Higher Vocational Certificate Students: A Case Study of SNC Former Public Company Limited *Mr. Apichai Khantee*
12.00-12.20	22 Years on: Reflections on a Major Real-life Learning Experience for Singapore Students Studying Microhydroelectricalgeneration in the Villages along the Everest Trek in 1991. *Mr. Martin Allinson*
12:20-13:00	**Lunch Time**
13.00 -14.00	**Panel Discussion (please go to Room 701)**
14.00 -14.20	**Coffee Break**
14.20 -16.20	**Chairs : Asst. Prof. Prasert Kenpankho and Ajarn Sunti Tuntrakool**
14.20 -14.40	A Relationship between Word Recognition Ability and Socio-Economic Variables of Second Year College Students, Faculty of Agricultural Products, Maejo University *Ms. Thatree Rodchamnan*
14.40 -15.00	A Study of Thai Nurses'Persuasive Strategies and Their Impact on Foreign Patients' Health Behavior *Ms. Cholthicha Akkapholdachachai*
15.00 -15.20	Implementation of Seven Habits of Highly Effective People in Physics Instructional for Constructing the Leadership of Students *Mr. Agusta Danang Wijaya*
15.20 - 15.40	Voices from a Low Vision Student *Ms. Sirion Rattanaudom*
15.40 -16.00	A Study of Factors Influencing KMITL Students in Their Choice of Place to Stay during Their Study *Dr. Ampapan Tuntinakhongul*

IMPROVING PROBLEM-SOLVING SKILLS FOR UNDERGRADUATE MECHANICAL TECHNOLOGY: A CASE STUDY OF MECHANICAL SYSTEM MODELING

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ABSTRACT

Recently, mechanical system modeling (MSM) is widely suggested for simulations and experiments of increasingly considerable where the amount of problem-solving skills is vast and the sequence of steps required identifying the analysis or solution of the resulting mathematical problem. In this study, concept mapping tool (CMT) is presented to help solve student diagnosis problem using not only the conventionally features but also the extracted features of the dynamic behavior of a system using a computer-based solution. CMT has the advantage that it provides students to support problem solving as a learning strategy. Students could be generated idea to help organize problem representation and existing knowledge about a topic by relating concepts. This study aimed to propose a framework that includes essential dimensions of learning to be considered when instructors scaffold student *problem-solving skills in mechanical system modeling. The implication is then supposed to implement as a general paradigm for specific applications generally referred to efficiency and effectiveness in learning. Moreover, a combination of interpreting methods, such as LabVIEW simulator programming and MATLAB representation programming is integrated.*

Keywords: Concept Mapping Tool, Learning Strategy, Mechanical System Modeling, Problem-Solving Skills, Undergraduate Mechanical Technology

INTRODUCTION

The point of views about the most desirable 21st century learning skills in Higher Education has received significant attention towards the educational reforms. With development, students often shift views include the importance of thinking skills (critical thinking, problem-solving, innovative and creative thinking), social skills (collaboration, communication, connectedness), tools for learning (information and communication technology), and broader community skills (personal and social responsibility, citizenship, life and career-related skills). Further development is strongly advised in regard to 21st century learning skills that often imply constructivist pedagogies (Berry, 2010; Chapman, 2013; Lee, 2012).

In the present context, undergraduate mechanical technology students almost always shift from using inefficient strategies for solving problems in the topic of MSM according to 5593510 Automotive Engineering Subject of the Mechanical Technology program, Faculty of Industrial Technology at Nakhon Si Thammarat Rajabhat University. This shift was observed by researchers, including the dynamic behavior of a system with the concepts of equivalence, degrees of freedom, and constrained.

One reason students may use incorrect strategies to solve problems is that they fail to accurately problem representation of the points. They do not understand the dynamic behavior of a system with the concepts of equivalence, degrees of freedom, and constrained are very important. With development, problem representation refers to “the internal depiction or re-creation of a problem in working memory during problem solving” (Rittle-Johnson, Siegler, & Alibali, 2001, p. 348). The statement has been affected students’ learning achievement. Because of MSM are extremely important of the wide use of because of the plane dynamics of a vehicle activated.

In industrial technology education, researchers analyzed how a CMT of constructing mathematical model is proposed for improving problem-solving skills. With computer-based solution has been long-standing, progress has been slow. For instance, problem solving for inquiry in technology has proven especially popular (Krajcik & Blumenfeld, 2006; Linn, 2006), of implementation, effectiveness and system use suggests that instructors, students, and technology interact differently in controlled versus real-world, everyday universities settings. Because of the utility of concept maps in the university environment (Novak, 1988) and the convenience, self-controlled learning pace and high expectations of web-based learning (Cline, Brewster, & Fell, 2010), researchers provided a web-based CMT for teaching and learning of student learning as shown in Figure 1.

Students can use CMT create concept maps relative to a real-world setting. CMT supports the construction of concept maps by students and the automatic evaluation of these maps by comparing them to a criterion concept map developed by the instructor of a course. CMT consists of the following components:

- A concept map drawing applet, written in the Java programming language, that is used for concept map assignment authoring by the instructor, construction of concept maps by students, and for providing customized feedback.
- Web pages created using Java ServerPagers (JSP) that perform authentication and record keeping and connect to the concept map drawing applet, instructor authoring pages, and the rule-based assessment tool.

- A MySQL database that contains information about the instructor and student concept maps, people and their roles, and assessment scores.
- A rule-based evaluation system that uses the Java Expert System Tool (Jess) (Friedman-Hill, 2008).

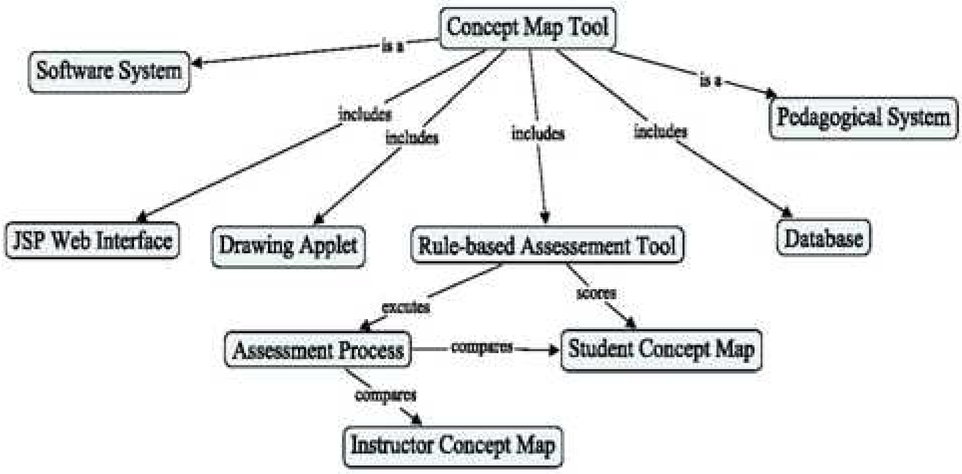


Figure 1 Concept Mapping Tool

The accurately represent key features of the problems can be associated with one or more problems. For each topic in which an individual is a member, his/her is either problem representation instructor or student. Within CMT, an instructor can create a concept map assignment by providing an assignment name and a top-level concept. The concept map drawing applet is then presented to the instructor who draws nodes and arcs to create a concept map (a criterion concept map) that is based on material presented in the classroom and that reflects meaningful learning relative to the top-level concept. Additionally, concept maps are one of the tools that students can use to help organize new and existing knowledge about the topic by relating concepts in a way that promote successive and progressive changes in learning along the rote learning/meaningful learning continuum (Novak et al., 2000).

PURPOSE

This study aimed to propose a framework that includes essential dimensions of learning to be considered when instructors scaffold student problem-solving skills in mechanical system modeling.

DESIGN

SCAFFOLDING PROBLEM-SOLVING SKILLS

The term and defined scaffolding stated as assistance from experts that enables students to beyond the learning achievement. Conceptualization of scaffolding was consistent with Vygotsky's model of instruction and emphasizes the teacher's role as a more knowledgeable learner to help learners to solve problem-oriented tasks (Vygotsky, 1978). While problem solving is a goal in educational reform, researchers have advanced markedly different conceptions and methods of study. Vygotsky (1978) proposed five steps on problem-solving skills scaffolding:

- Identification and engagement,
- Exploration,
- Reconstruction,
- Presentation and communication,
- Reflection.

Gagné and Briggs (1974), for example, regarded problem solving as complex combinations of hierarchically-ordered intellectual skills. Constructivists, such as Vygotsky (1978), conceived of the zone of proximal development as the gap between "actual developmental level as determined by independent problem solving" and the level of "potential development as determined through problem solving under adult guidance or in collaboration with more able peers" (p. 86).

Numerous problem-solving approaches and associated learning activities have been proposed, reflecting diverse theoretical framework such as information processing, cognitive science and constructivism (Mayer & Wittrock, 2006; Paas & van Merriënboer, 1994). As a result, researchers found diverse approaches to problem solving in order to compare assumptions and identify where problem representation was feasible. A Hungarian mathematician (Polya, 1957), who designed problem-solving processes, analyzed conversations between teachers and students in mathematics classrooms. Polya proposed four problem-solving steps:

- understanding the problem,
- devising a plan,
- carrying out the plan, and
- Looking back at work.

These activities, often combined with heuristics (e.g., analogy, generalization, induction, specialization, etc.), outline the largely linear process Polya noted during students' problem solving. Extending Polya's approach, Bransford and Stein (1984) developed a 5-stage problem-solving model that includes

- identifying problems and opportunities,
- defining goals,
- exploring possible strategies,
- anticipating outcomes and acting, and
- Looking back and learning.

They found that individuals become effective and creative problem solvers when they analyze their own strategies and apply alternative approaches to their problems. To varying extents, these stages are integral to contemporary problem-solving models. Jonassen (2007) identified ill-structured problems for which no single methods or answers exist, including story problems, rule-using and rule-induction problems, decision-making problems, troubleshooting problems, policy problems, design problems, and dilemmas. Jonassen (2000) explained that problem dimensions included internal factors that address problem solvers' individual characteristics (e.g., problem solvers' prior experience, domain knowledge, reasoning skills, and epistemological beliefs) and external factors that reflect how problems are formed and represented (e.g., complexity, structuredness, dynamicity) and situated (e.g., cultural expectations).

MECHANICAL SYSTEM MODELING REPRESENTATION

The fundamental dynamics system and modeling use quantitative mathematical models of physical systems to design and analyze control systems. The dynamic behavior is generally described by ordinary differential equations. MSM will consider a wide range of systems, including mechanical, hydraulic, and electrical. Since most physical systems are nonlinear, linearization approximations, which allow us to use Laplace transform methods. MSM will then proceed to obtain the input–output relationship for components and subsystems in the form of transfer functions. The transfer function blocks can be organized into block diagrams or signal-flow graphs to graphically depict the interconnections. Block diagrams (and signal-flow graphs) are very convenient and natural tools for designing and analyzing complicated control systems (Vu & Esfandiari, 1998).

In this study, researchers convinced students throughout understand conceptual framework namely "Six step approach to dynamic system problems". Researchers applied the LabVIEW simulator programming and MATLAB representation programming to encourage students for solving the problems in system response. Technology-enhanced classrooms introduced a reduced concentration of ultimately planned to conduct the study on MSM with computer programming have the following:

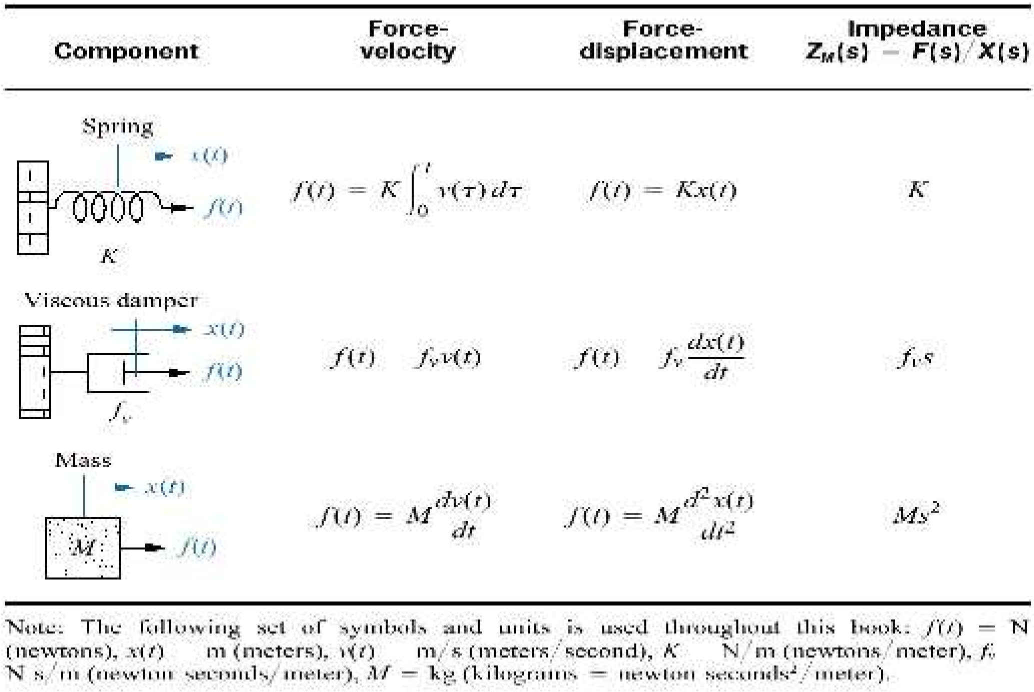
- Define the system and its components with mechanical elements as shown in Figure 2. The five procedures have the following:
  1. Mass Element (translational mass and rotational mass)
  2. Spring Element (translational spring and rotational spring)
  3. Damper Element are three types of damping in engineering mechanics
     - Viscous damping (with fluid)
     - Coulomb damping (dry friction)
     - Structural damping (hysteresis damping)
  4. Equivalence is convenient in many applications.
  5. Degree of Freedom is defined as the number of independent generalized coordinates that specify the configuration of the system.
- Formulate the mathematical model and list the necessary assumptions:
  1. Basic (idealized) modeling elements and free body diagram as shown in Figure 3
  2. Interconnection relationships –Newton's laws
  3. Students are derived equations of motion that describe the behavior of a physical system and relationships of MSM in terms of its motion as a function of time. Researchers are trials conducted for teaching within the sixteen steps as follow as:

     Velocity (m/s)

$$v = \dot{x} = \frac{d}{dt}x \qquad \text{------- (1)}$$

     Acceleration (m/s^2)

$$a = \frac{dv}{dt} = \frac{d}{dt}\left(\frac{d}{dt}x\right) = \frac{d^2}{dt^2}x = \ddot{x} \qquad \text{------- (2)}$$



Component	Force-velocity	Force-displacement	Impedance $Z_M(s) = F(s)/X(s)$
Spring ($x(t)$, $f(t)$, K)	$f(t) = K\int_0^t v(\tau)\,d\tau$	$f(t) = Kx(t)$	K
Viscous damper ($x(t)$, $f(t)$, f_v)	$f(t) = f_v v(t)$	$f(t) = f_v \frac{dx(t)}{dt}$	$f_v s$
Mass ($x(t)$, M, $f(t)$)	$f(t) = M\frac{dv(t)}{dt}$	$f(t) = M\frac{d^2x(t)}{dt^2}$	Ms^2

Note: The following set of symbols and units is used throughout this book: $f(t)$ = N (newtons), $x(t)$ = m (meters), $v(t)$ = m/s (meters/second), K = N/m (newtons/meter), f_v = N-s/m (newton-seconds/meter), M = kg (kilograms = newton-seconds²/meter).

Figure 2 Relationships of mechanical translational systems (Nise, 2000)

Power (N/m-s)

$$p = f \cdot v = f \cdot \dot{x} = \frac{d}{dt} w \qquad \text{------- (3)}$$

Energy (N/m)

$$w(t_1) = w(t_0) + \int_{t_0}^{t_1} p(t)\, dt \qquad \text{------- (4)}$$

$$= w(t_0) + \int_{t_0}^{t_1} (f \cdot \dot{x})\, dt \qquad \text{------- (5)}$$

- Researchers use quantitative mathematical models of physical systems to design and analyze control systems. The dynamic behavior is generally described by differential equations, which consider a wide range of systems. Since most physical systems are nonlinear, researchers discussed linearization approximations, which use Laplace transform methods. Write the differential equations describing the model and solve the equations for the desired output variables. The procedure of drawing MSM on CMT has the following:

  1. Write the Newton's Second Law

$$\downarrow + \sum F_x = ma \downarrow + \qquad \text{------- (6)}$$

$$f(t) - bx - kx = mx\cdot \qquad \text{------- (7)}$$

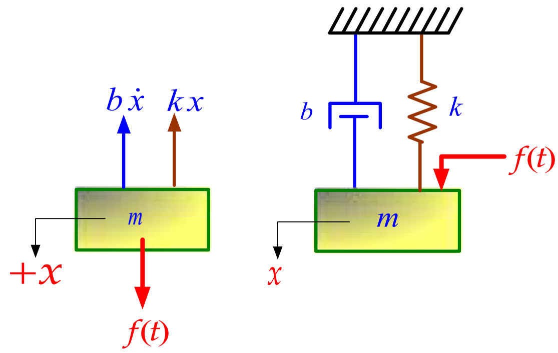


Figure 3 Mass-Spring-Damper Systems and Free Body Diagram (Vu & Esfandiari, 1998)

2. Rearrange the differential equation and the standard input-output equation form

$$m\frac{d^2x}{dt^2} + b\frac{dx}{dt} + kx = f(t) \qquad \text{------- (8)}$$

$$mx\cdot + bx + kx = f(t) \qquad \text{------- (9)}$$

3. Write the transfer function by taking the Laplace transform of both sides the predicting equation with all the initial conditions set to zero

$$[ms^2 + bs + k]\, X(s) = F(s) \qquad \text{------- (10)}$$

$$G_x\ (s) = \frac{X\,(s)}{F\,(s)} \qquad \text{------- (11)}$$

$$= \frac{1}{ms^2 + bs + k} \qquad \text{------- (12)}$$

Since $v\,(t) = x(t)$, the transfer function relating the input $f(t)$ to the output $v\,(t)$ is

$$G_v\ (s) = \frac{s}{ms^2 + bs + k} \qquad \text{------- (13)}$$

4. A state-space representation is readily obtained from the differential equation

$$x = -\frac{k}{m}x - \frac{b}{m}\,x + \frac{1}{m}\,f(t) \qquad \text{------- (14)}$$

5. Write the input-output equation in matrix form

$$\begin{Bmatrix} x_1 \\ x_2 \end{Bmatrix} = \begin{bmatrix} 0 & 1 \\ -k/m & -b/m \end{bmatrix} \begin{Bmatrix} x_1 \\ x_2 \end{Bmatrix} + \begin{Bmatrix} 0 \\ 1/m \end{Bmatrix} u \qquad \text{(state equation)} \qquad \text{------- (15)}$$

$$y = \begin{bmatrix} 1 & 0 \end{bmatrix} \begin{Bmatrix} x_1 \\ x_2 \end{Bmatrix} + 0.\,u \qquad \text{(output equation)} \qquad \text{------- (16)}$$

- Examine the solutions and the assumptions was supplemented by LabVIEW programming as shown in Figure 4

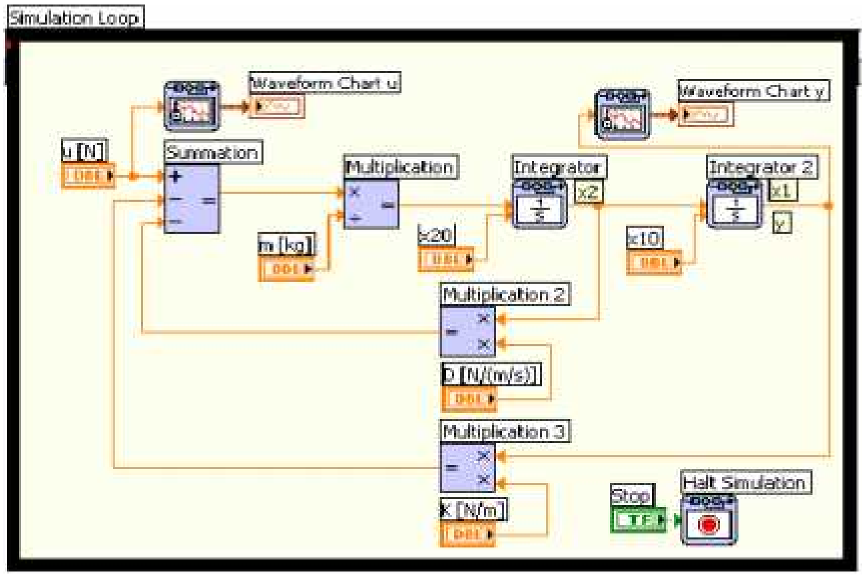


Figure 4 A block diagram of the mass-spring-damper system simulator in LabVIEW (Kalluri, 2006)

- Students were doing the mass-spring-damper system simulator in LabVIEW programming as shown in Figure 5.
- In Figure 6, students investigated and discussed the MSM response with MATLAB representation of transfer functions. If necessary, reanalyze or redesign the system.

DEVELOPMENT

Researchers have employed five problem-solving activities (Vygotsky, 1978):

- Problem identification and engagement is conceptualized as making observations: generating/finding/posing questions;
- Evidence exploration is conceptualized as examining resources: planning, investigations and utilizing tools in the learning process;
- Explanation reconstruction is conceptualized as proposing answers, explanations, and predictions;
- Communication and justification of explanation is conceptualized as communicating the results and;
- Revision and reflection of explanation is conceptualized as justifying/defending/revising the ideas/theories as active diagnosis and ongoing assessment (Kim & Hannafin, 2007).

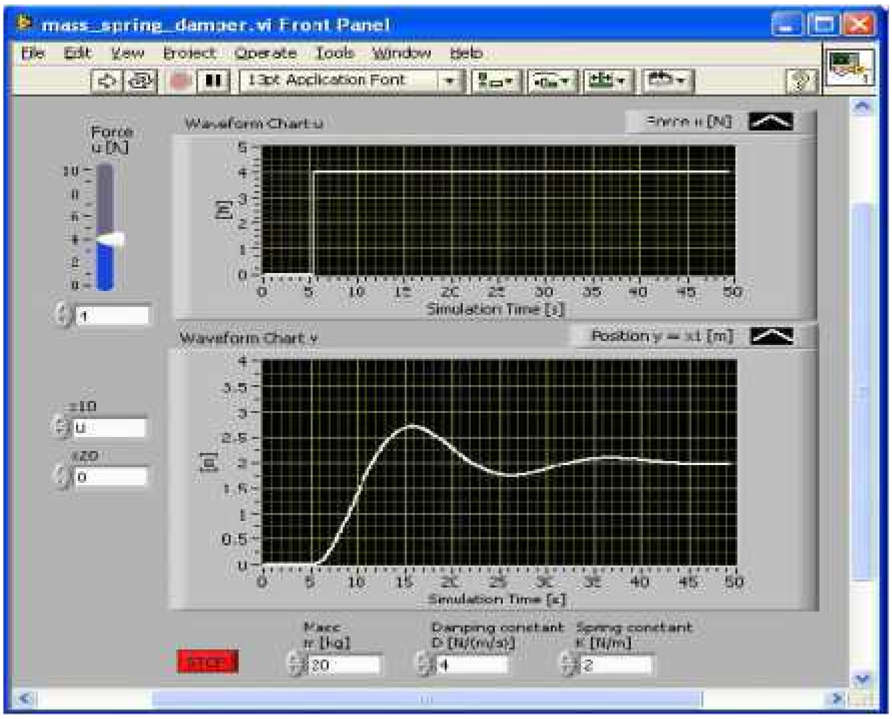


Figure 5 The mass-spring-damper system simulator in LabVIEW (Kalluri, 2006)

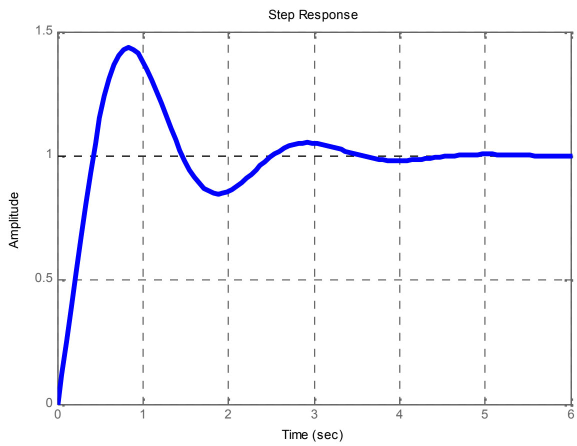


Figure 6 MATLAB representation of transfer functions (Nise, 2000)

Problem representation embodies student concept maps, such as making observations of MSM by analyzing and utilizing computers in technology-enhanced classrooms. The learning context as shown in Figure 7 where a real-world problem can be found serves to help students to:

1) Recognize (the five) situations: problem identification, evidence exploration, explanation reconstruction, communication and justification, and revision and reflection. When they have been occurred in simple or complex problems via CMT; Presented the fundamental

dynamics system and modeling use quantitative mathematical models of physical systems to design and analyze control systems.

2) Understand the relationships expressed in real-world problems such as classification of interesting systems,
3) Formulation the logical reasoning (causes and effects) in the problems to his or her own knowledge to find out the dynamic behavior is generally described by differential equations.
4) Implementation CMT situational knowledge to identify the essential parts of any conditions, specifying correctly those that are known or unknown to generate the mathematical analysis; therefore, MSM will consider a wide range of systems, including mechanical, hydraulic, and electrical. Since most physical systems are nonlinear, linearization approximations, which allow us to use Laplace transform methods.
5) Interpretation a reasonable strategy for solving the problem as the mathematical results; MSM will then proceed to obtain the input–output relationship for components and subsystems in the form of transfer functions.
6) Evaluate his or her understanding of the situation to select appropriate of mathematical modeling; block diagrams (and signal-flow graphs) are very convenient and natural tools for designing and analyzing complicated control systems (Edwards & Penny, 1996).

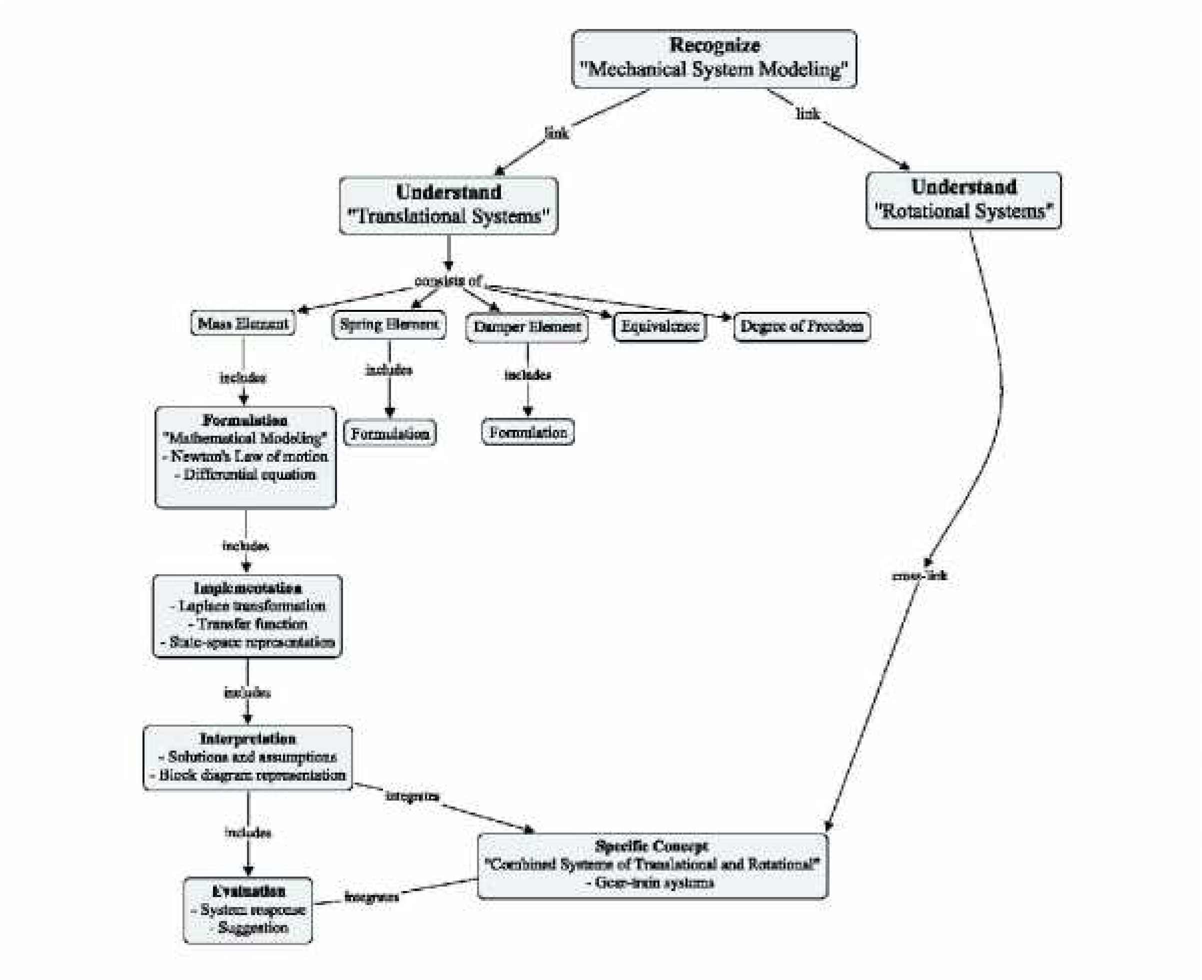


Figure 7 The structure of a framework on MSM via CMT in Automotive Engineering Subject

IMPLICATION

According to the definition of a concept map proposed by Novak and Gowin (1984), each concept map can be taken as the abstraction of a "hierarchical graph", that is, a graph with a hierarchical structure as a knowledge structure. In Figure 7, CMT is derived from the graph theory, as follows:

(1) A concept map is taken a hierarchical directed graph as a knowledge structure;
(2) Every domain concept is problem representation as a node;
(3) The relationship between a pair of concepts is represented by an edge, which is formally defined by an ordered pair of two nodes;
(4) A branch of concept map is seen as a sub-tree of the hierarchical directed graph;
(5) A cross-link joins two branches.

This study has consistently shown that when students lack problem representation knowledge, they experience problems attempting to solve even well-structured problems (Shin, Jonassen, & McGee, 2003). This view is critical in problem-solving environments, which are typically ill-structured and rely heavily on students' ownership over their learning. To illustrate the notion of information uncertainly in the concept mapping context, when learners lack adequate prior knowledge, the prior experiences and knowledge may limit or fail to adequately inform their inquiry processes (Jonassen, 2000). As for the fundamental structural properties of MSM via CMT, it was interesting to find that integration was potentially exact to individuals' problem-solving skills, whereas complexity was essentially correct to teach for increasing problem-solving skills.

To overcome such challenges, problem identification activities may be scaffolding through "CMT" to structure and guide student knowledge of engineering education, to formulate new ideas and paradigms, and to revise emergent understanding using technologies that support or contradicts (Sudsomboon, 2010). When students are unable to generate appropriate problem representation, instructors can scaffold or model problem solving procedures, provide plausible hypotheses and offer multiple perspectives. Technologies can customize prompts to account for differences in prior knowledge and characteristics specific to problem solving processes.

CONCLUSIONS AND FUTURE WORK

Based on the notion of learning strategy in this study, researchers have developed a framework for proposing can be used to enhance problem-solving skills in the topic of MSM. The learning outcomes was captured by existing CMT, to provide students problem-solving skills has been including the dynamic behavior of a system with the concepts of equivalence, degrees of freedom, and constrained. The results show the proposed framework is immediately effective in performing individuals' problem-solving skills in the novice university students.

The limitation of study were undergraduate mechanical technology students who had not experience in the fundamental of engineering mathematics (Linear algebraic and vector calculus and Differential equation), which has been great problems in Faculty of Industrial Technology at Rajabhat University. As a result, their concept map included a high level of uncertainly than is usual among students. In future research, researchers interested extend to test and experiments in the long term course. Both ill-structured and well-structured real-world problems in the mechanical engineering areas were integrated. The investigation of effects and evaluation on concept mapping within learning environment should explore the existing knowledge as well.

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