วารสารวิชาการเทคโนโลยีอุตสาหกรรม มหาวิทยาลัยราชภัฏนครศรีธรรมราช
ปีที่ 8 ฉบับที่ 1 มกราคม – ธันวาคม 2558

การออกแบบยุทธวิธีการเรียนรู้เพื่อพัฒนาทักษะการคิดเชิงวิจารณญาณสำหรับการวิเคราะห์แบบจำลองทางคณิตศาสตร์ของระบบทางกล

วีระยุทธ สุดสมบูรณ์ [1*] รอยพิมพ์ใจ เพ็ชรกุล[1] วีรพล ปานศรีนวล[1] ฉัตรชัย แก้วดี [2] มนตรี เรืองประดับ [3]
วิทยา วงษ์กลาง [3] และ ปริญญา หม่อมพิบูลย์ [3]

บทคัดย่อ

การวิจัยครั้งนี้มีวัตถุประสงค์ (1) เพื่อออกแบบยุทธวิธีการเรียนรู้ในการพัฒนาทักษะการคิดเชิงวิจารณญาณสำหรับการวิเคราะห์แบบจำลองทางคณิตศาสตร์ของระบบทางกลด้วยวิธีการอ้างอิงโดยใช้ฐานกรณี (2) เพื่อเปรียบเทียบผลสัมฤทธิ์ทางการเรียนของผู้เรียนก่อนและหลังเรียนด้วยยุทธวิธีการเรียนรู้ในการพัฒนาทักษะการคิดเชิงวิจารณญาณสำหรับการวิเคราะห์แบบจำลองทางคณิตศาสตร์ของระบบทางกลด้วยวิธีการอ้างอิงโดยใช้ฐานกรณี กลุ่มตัวอย่างที่ใช้ในการวิจัย ได้แก่ นักศึกษาระดับปริญญาตรีชั้นปีที่ 3 และ 4 สาขาเทคโนโลยีเครื่องกล คณะเทคโนโลยีอุตสาหกรรม มหาวิทยาลัยราชภัฏนครศรีธรรมราช ภาคการศึกษาที่ 1/2557 จำนวน 31 คน ด้วยการเลือกกลุ่มตัวอย่างแบบเจาะจง สำหรับการจัดการเรียนการสอนในรายวิชา 5593716 เทคโนโลยีซีเอ็นซี เครื่องมือที่ใช้ในการวิจัยในครั้งนี้ คือ การสังเคราะห์เอกสารและงานวิจัยที่เกี่ยวข้อง และแบบทดสอบก่อนเรียนและหลังเรียน สถิติที่ใช้ในการวิเคราะห์ข้อมูล ได้แก่ ค่าเฉลี่ย ส่วนเบี่ยงเบนมาตรฐาน และการทดสอบความแตกต่างระหว่างค่าเฉลี่ยที่มีกลุ่มตัวอย่างสัมพันธ์กัน ผลการวิจัยพบว่า ยุทธวิธีการเรียนรู้ที่พัฒนาขึ้นประกอบด้วย 5 ขั้นตอน คือ 1) การค้นหากรณีศึกษา 2) การรื้อฟื้นความรู้โดยวิเคราะห์กรณีศึกษา 3) การแก้ปัญหาตามรายกรณีศึกษา 4) การทดสอบกรณีศึกษา และ 5) การปรับปรุงกรณีศึกษา และผลสัมฤทธิ์หลังเรียนด้วยยุทธวิธีการเรียนรู้ที่พัฒนาขึ้นมีค่าคะแนนเฉลี่ยสูงกว่าก่อนเรียนแตกต่างกันอย่างมีนัยสำคัญทางสถิติที่ระดับ .05 และสามารถนำไปประยุกต์ใช้ในการพัฒนาการเรียนการสอนทางเทคโนโลยีอุตสาหกรรมได้เป็นอย่างดี

คำสำคัญ การอ้างอิงโดยใช้ฐานกรณี / ทักษะการคิดเชิงวิจารณญาณ / ยุทธวิธีการเรียนรู้ / ระบบทางกล

[1] อาจารย์ หลักสูตรครุศาสตรมหาบัณฑิต สาขาวิชาเทคโนโลยีอุตสาหกรรม คณะเทคโนโลยีอุตสาหกรรม มหาวิทยาลัยราชภัฏนครศรีธรรมราช

[2] ผู้ช่วยศาสตราจารย์ หลักสูตรครุศาสตรมหาบัณฑิต สาขาวิชาเทคโนโลยีอุตสาหกรรม คณะเทคโนโลยีอุตสาหกรรม มหาวิทยาลัยราชภัฏนครศรีธรรมราช

[3] อาจารย์ สาขาวิชาเทคโนโลยีเครื่องกล คณะเทคโนโลยีอุตสาหกรรม มหาวิทยาลัยราชภัฏนครศรีธรรมราช

[*] ติดต่อผู้นิพนธ์ โทร.089-477-6487 อีเมล์ weerayute_sud@nstru.ac.th

วารสารวิชาการเทคโนโลยีอุตสาหกรรม มหาวิทยาลัยราชภัฏนครศรีธรรมราช
ปีที่ 8 ฉบับที่ 1 มกราคม – ธันวาคม 2558

Designing of a Learning Strategy for Critical Thinking Skills Development on Analytical Mathematical Modeling of Mechanical System

Weerayute Sudsomboon [1*] Roipimjai Petchkul [1] Weeraphol Pansrinuan [1] Chatchai Kaewdee [2]
Montri Reungpradub [3] Wittaya Wongklang [3] and Parinya Mhompibool [3]

Abstract

The objectives of this research were: (1) to design a learning strategy for critical thinking skills development on analytical mathematical modeling of mechanical system; and (2) to compare the learning achievement pre and post test through a learning strategy for critical thinking skills development on analytical mathematical modeling of mechanical system. The subjects were 31 senior undergraduate mechanical technology students at Faculty of Industrial Technology, Nakhon Si Thammarat Rajabhat University in semester 1/2014. The sampling size was selected by purposive sampling for teaching and learning in 5593716 CNC Technology course. The research instrumentation was literature reviews synthesis within pre-post test. Data were analyzed by mean, standard deviation, and *t*-test dependent. The results revealed that a learning strategy for critical thinking skills development on analytical mathematical modeling of mechanical system was five steps as follow as: 1) new case, 2) retrieved case, 3) solved case, 4) tested case, and 5) learned case. The post-test mean score was higher than pre-test with the statistically significance difference at .05. Furthermore, this research was also some suggestions of use learning strategy, that support students' thinking and reasoning respectively.

Keywords: Case-based reasoning / Critical Thinking Skills / Learning strategy / Mechanical system

[1] Lecturer, Graduate Program in Industrial Technology, Faculty of Industrial Technology, Nakhon Si Thammarat Rajabhat University
[2] Assistant Professor, Graduate Program in Industrial Technology, Faculty of Industrial Technology, Nakhon Si Thammarat Rajabhat University
[3] Lecturer, Mechanical Technology Program, Faculty of Industrial Technology, Nakhon Si Thammarat Rajabhat University
[*] Corresponding Author: Tel. 089-477-6487; Email: weerayute_sud@nstru.ac.th

1. Introduction

Today's, the Faculty of Industrial Technology (FIT) at Nakhon Si Thammarat University (NSTRU) is dealing great efforts to transform from a local university to a research university in area of excellences, so the high demands for reforming technology education to foster quality technologists required by industrials are put forward. But traditionally technology education in FIT, NSTRU is detached from or lags behind the rapidly growing industry demands, and the connection between enterprises and universities is not close enough.

However, it has not been commonly evidenced that critical thinking skills development increase both learning and enjoyment during coursework in FIT, NSTRU. Researchers have currently introduced the Bachelor of Science (B.S.) in Mechanical Technology program and the current students studied 5593716 CNC Technology course in the semester 1/2004. This paper attempts to bridge the critical thinking skills development gap between Mathematical Modeling and Mechanical Technology graduates. It has been widely acknowledged that all mechanical technologist must be employed with CNC machines as career professionals regardless of their specialization.

The initial curriculum was developed in such a way that 60% of the courses taken by practical pedagogy. Hence, mechanical students were not identical to know 'how to design' and or 'how to control of mechanical systems'. The remaining 40% are specialization courses related to advanced mechanical technology such as, CNC machines, PLC with pneumatic and hydraulics, and robotics. There are least lectures for teaching the mechanical technology by integrating analytical mathematical modeling in this area. It affects of a wide range of students that demonstrate the numerical skills, knowledge application and integration of knowledge taught in projects to create practical intelligent products or systems.

Ogata [1] describes this modern trend is to combine mathematical modeling, theoretical analysis, and computer simulation. However, it is generally viewed that changing technology students to enhance the ways knowledge and skills are used in real world practice. While this may be true for provides some preliminary mathematical concepts and methods that play essential practices for analyzing of dynamic systems in Computer Numerical Control (CNC) Machines.

In fact, mechanical technology students lack necessary basic numerical skills as well as higher order thinking skills; today's workplaces often demand high competencies of both skill sets. Currently, CNC machines are found almost everywhere, from small job shops in rural communities to fortune in large companies. The technologist is hardly on demand as a facet of manufacturing that is not in some way touched by what these innovative machine tools can do. Students' have involved in the manufacturing environment should be well aware of what is possible with these sophisticated machine tools. Among these forces is globalization of the workplace, decision-making, modernized production, new technologies, and multiple roles on knowledge workers. Thus, mechanical technology program is revamping their instructional strategy to focus on problem solving as a key component of the industrial educational leader in professional curriculum.

The objectives of this research were: (1) to design a learning strategy for critical thinking skills development on analytical mathematical modeling of mechanical system; and (2) to compare the learning achievement pre and post test through a learning strategy for critical thinking skills development on analytical mathematical modeling of mechanical system.

2. Theoretical Background

2.1 What is a critical thinking skills development in this study?

Mechanical technology education aims to promote quality of the problem-solving skills by engaging theoretical, and develops real-world problem-solving on social demands to improve future technologist competencies [2]. One of the most widely used well completion challenges to promote well teaching and learning effectively in mechanical engineering education is dynamic system and modeling analysis Due to its highly learning achievement and applications, its deal with the mathematical modeling of well dynamic systems and response analyses of such systems with a view toward understanding the dynamic nature of each system and improving the system's performance in Computer Numerical Control (CNC) Machines [1].

While interest in technology changes has been affected to improve problem-solving skills, students has been lack. Hannafin and Land [3] stated that teachers hold traditional teaching methods, didactic beliefs and use "conventional ways" without sustainable development for student-centered problem solving. For this reason, researchers were analyzing many researches and journals related to dynamic system and modeling analysis, teaching and learning, and technology-enhanced scaffolds for designing problem-solving, implications for real-world engineering education [4], [5].

As a result, Case-Based Reasoning is fit to employ as the problem solving technique that uses and adapts the solutions of analogous past problems to solve new problems [6]. The competitive advantage is gain an ample portion of these background knowledge and skills. The ideas are supposed to conduct teaching and learning in 5593716 CNC Technology course in semester 1/2014. With this reason, students often learn facts and rote procedures to link the analytical reasoning and application of knowledge. Problem solving has become the conceptualized as rejoin content and application in a modern learning environment for basic skills as well as their application in various contexts.

On the other hand, CBR is a heuristic-intensive and highly dispersed and modern innovative expertise integrated system which affects the decrease efficiency for students learning the following: (1) CBR is problem-solving skills in critical thinking to meet the specific competences of individual pace; (2) CBR takes computer technology as its foundation; and (3) CBR can perfectly meet the requirements of lecturers and power consumption of different students application. Since the students must be prepared the critical thinking skills for previously (e.g., numerical skills, information technology skills, engineering design skills, control engineering skills) that is based on the utilization of CBR can enable much more promote Mechanical Technology program and the current students studied 5593716 CNC Technology course.

2.2 Analytical of Case-Based Reasoning

CBR stated as a heuristic human problem solving behavior that has been adapted for computer use. It is based on recall and reuse of specific “cases” and offers techniques for acquiring, representing and managing previous experiences. The CBR cycle have four-step process of retrieve, reuse, revise, and retain is detailed as shown in Figure. 1.

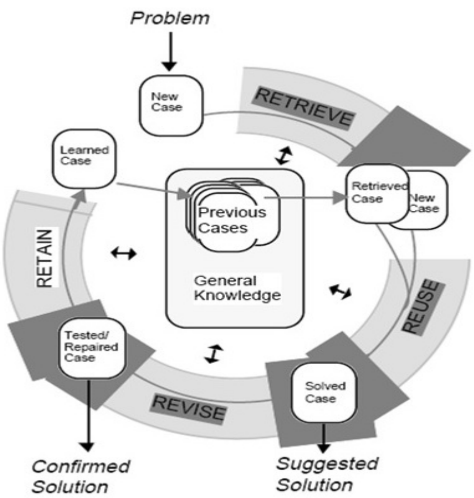

Figure 1 The CBR cycle [7]

- ***Retrieve***: The process of finding cases, and their corresponding solutions, in the dataset or knowledge base that are most relevant to the given case.
- ***Reuse***: The process of mapping the most common solution from the knowledge base for the given case. The reuse process also allows for adaptation of the most common solution, as needed, through the use of rules or “if statements” incorporated into the system.
- ***Revise***: The process of testing the new solution. If the new solution is successful, the process moves directly to retain. If the new solution does not work as expected or needs additional fine-tuning, the solution is further adapted to achieve the desired result.

- ***Retain***: The process of storing the new case and its final solution in the knowledge base for future use in the case-based reasoning process.

Furthermore, CBR is a model of cognition strategy in which individuals construct schemas based on their interpretations of particular situations (cases or stories), store these in memory, and prior knowledge to construct a new situation through a process of analogical reasoning [8], [9]. An individual possesses a store of cases that are interpretations of students' experiences. When cases are stored, they are 'indexed' in the memory and the indexes for a case enable a person to locate and retrieve a relevant case or cases when confronted by a new situation.

Using the past experience might also be constructed when coming to understand the new situation, causing a case to be 're-indexed' [10]. Then, CBR is suitable to conduct in the study that considered a 'natural' form of students' reasoning, their prior knowledge to make sense of new situations [11].

2.2 Case-based reasoning instructional strategy (CBRIS)

When used the CBRIS as an instructional strategy, CBR is thought to teach students' understand mathematical modeling and analysis of mechanical systems for a particular situation (the case), identify the range of issues involved in memory in the specific case, make decisions, and suggest solutions, and formulate principles for handling future situations. This approach can enhance students to link theory and practice by offering a means to contextualizing learning in a way that connects content knowledge.

As novices, the benefit of CBR resides in its potential for developing a learning system that learns as new cases are solved. Learning occurs as a natural by-product of the process [6]. It is important to propose that CBR guide to solve problems effectively. For the application of mechanical engineering, each time a new solution is generated and a problem is solved, the experience is stored through the retain process to be used later on in solving similar problems. On the other hand, when the proposed solution to the problem fails, the reason for failure is identified and retained in order to avoid the same failure in the future [12].

The CBRIS design was often taught as a set of procedures accompanied by simple examples and experiment in laboratories. CBRIS has more recently emerged as a conceptualized to bridge this gap between theory and practice in instructional design education [13]. The CBIS model was employed by Ertmer and Russell [13], argued that CBIS approach as shown in Figure 1 are well-suited to conduct teaching instructional design that can be represented in the experimental model as follow as [14] [15] [16] [17] :

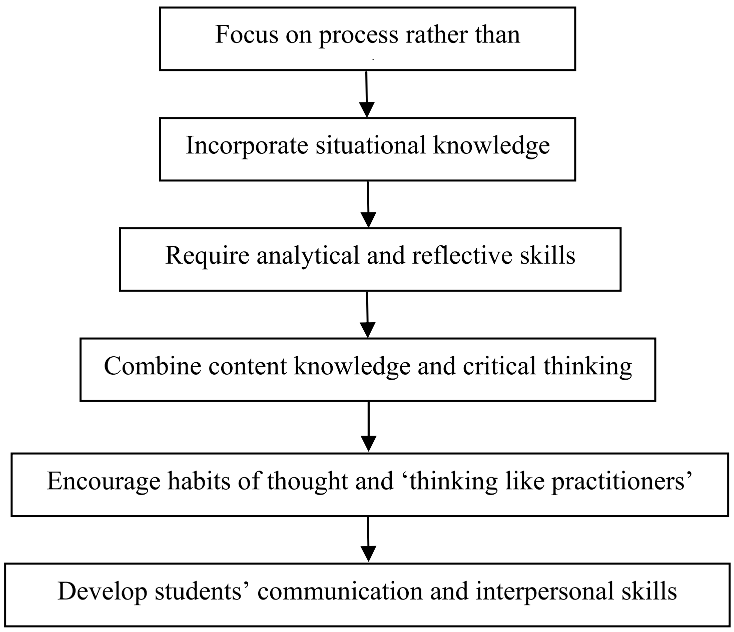

Figure 1 The theoretical framework

The CBR learning strategy can be linked the integration of realistic case studies into 5503901 Industrial Technology Research course in-depth insight to set problems and experience through mathematical modeling and analysis of mechanical system.

3. Research Methodology

3.1 Design

This research was one group pre-test and post-test design.

3.2 Subjects

The subjects were 31 senior undergraduate mechanical technology students at Faculty of Industrial Technology, Nakhon Si Thammarat Rajabhat University in semester 1/2014. The sampling size was selected by purposive sampling for teaching and learning in 5593716 CNC Technology course.

3.3 Research Instrumentation

The research instrumentation were literature reviews synthesis within pre-test and post-test. The 5 experts evaluated to select the suit item tests with IOC $\geq$ 0.6. The IOC results as whole as 0.78 and then tested try-out with non-sampling size 30 students to find reliability was at 0.84.

3.4 Data Collection

The four weeks were employed in data collection. Researchers taught students to enhance critical thinking skills via electronic journal data base. The 12 articles related CNC control on Non-holonomic mechanical systems (NHMS) was discussed individually. Researcher assigned students to represented 1) new case, 2) retrieved case, 3) solved case, 4) tested case, and 5) learned case to validate the learning strategy for critical thinking skills development on analytical mathematical modeling of mechanical system [17].

Students have been selected the similar case and measured critical thinking skills as follow as: problem-solving, decision making, analyzing, reasoning, and evaluating. Researchers taught the applicability of CBR as the adaptation knowledge to study the control of mobile manipulators presents a significant increase in the single mobile manipulator case.

This will impose students that: [17]

1) A set of kinematic and dynamic constraints was on the position and velocity of coordinated CNC control on NHMS as shown in Figure 2.

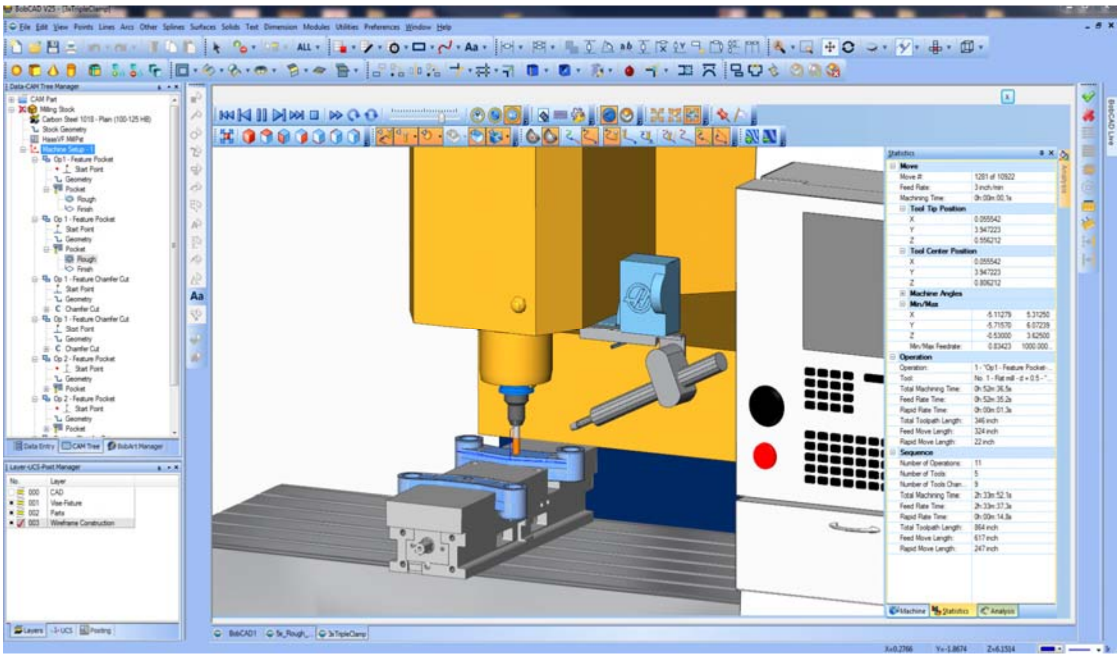

Figure 2 A set of kinematic and dynamic constraints on the position and velocity of coordinated CNC control on NHMS

2) The well NHMS datasets represent a tremendous amount of knowledge to idealize the relationships between kinematic modeling and dynamic modeling by eliminating the relative motion [18], [19], [20], [21].

The implication has determined the trajectories of points of the system. The equations of motion of the system associated as the generalized coordinates, and then applied a CBR in each of step:

1. *Index assignment*: students is searching the case as the generalized coordinates $\dot{x}_1$, $\dot{y}_1$, ξ and φ as shown in Figure 3,

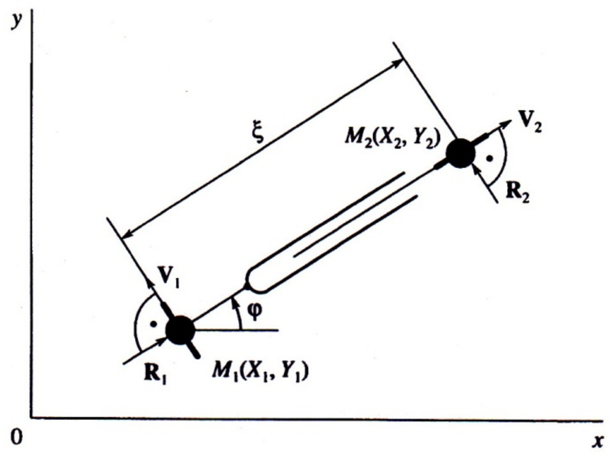

Figure 3 Non-holonomic mechanical systems [18]

$$\dot{x}_1 \cos\varphi + \dot{y}_1 \sin\varphi = 0,$$
$$\dot{x}_1 \sin\varphi - \dot{y}_1 \cos\varphi - \xi\dot{\varphi} = \sqrt{\dot{x}_1^2 + \dot{y}_1^2} - \xi\dot{\varphi} = 0$$

2. *Retrieve*: Solving the problem by taking $\dot{\xi}$ and $\dot{\varphi}$ as independent velocities, students can be obtained the equation

$$\dot{x}_1 = \xi\dot{\varphi}\sin\varphi, \quad \dot{y}_1 = -\xi\dot{\varphi}\cos\varphi$$

3. *Reuse*: Derived the kinetic energy of the system, provided that the masses of the point M_1 and M_2 can be written in the equation

$$T = \frac{1}{2}(\dot{x}_1^2 + \dot{y}_1^2) + (\dot{x}_2^2 + \dot{y}_2^2)$$

4. *Revise*: Finding the result of eliminating the dependent velocities in the expression for T^* using the constraints equations and formulate the equations of motion in Chaplygin form Fufagev & Neimark [11]

$$T = \frac{1}{2}(\xi\dot{\varphi}) + \frac{1}{2}(\dot{\xi})^2$$

$$\frac{d}{dt}\frac{\partial T^*}{\partial \dot{q}^\alpha} - \frac{\partial T^*}{\partial q^\alpha} + \frac{\partial T^*}{\partial q^\nu}\gamma^\nu_\alpha = 0$$

$$\gamma^\nu_\alpha = \frac{\partial \psi^\nu}{\partial q^\alpha} - \frac{d}{dt}\frac{\partial \psi^\nu}{\partial \dot{q}^\alpha}, \quad \dot{q}^\nu = \psi^\nu(q^\alpha, \dot{q}^\alpha)$$

$$\dot{q}^3 = \dot{x}_1 = \xi\dot{\varphi}\sin\varphi = \psi^3, \quad \dot{q}^4 = \dot{y}_1 = -\xi\dot{\varphi}\cos\varphi = \psi^4$$

Students obtain the following equations of motion:

$$\ddot{\xi} = 0, \quad (\xi\dot{\varphi})^{\cdot} = 0$$

These equations can be integrated in succession giving

$$\dot{\xi} = C_1 = \dot{\xi}_0, \quad \xi\dot{\varphi} = C_2 = \xi_0\dot{\varphi}_0$$

$$\xi = \dot{\xi}_0 t + \xi_0, \quad \varphi = \frac{\xi_0\dot{\varphi}_0}{\dot{\xi}_0}\ln(\dot{\xi}_0 t + \xi_0) + C_3$$

5. *Retain*: In the special case when $\dot{\xi}_0 = 0$, the point of M_2 can be at rest of radius ξ_0, while the point of M_1 will move uniformly over the circle.

If the point M_1 is at rest, the point M_2 will move uniformly along the fixed straight line. The boundary condition is: $\xi_0 = 1$, $\dot{\xi}_0 = 1$, $\varphi_0 = 1$, $\dot{\varphi}_0 = 1$

6. *Output*: Students solve the equation on the laws of motion of the points

$$y_s = -\frac{e^{s+1}}{2}\{\sin[\ln(t+1)] - \cos[\ln(t+1)]\} + \delta_{2s}(t+1)\cos[\ln(t+1)]$$

M_1 (s = 1, $\delta_{21} = 0$) and M_2 (s = 2, $\delta_{22} = 1$) Thus, the solution is:

$$x_s = \frac{e^{s+1}}{2}\{\sin[\ln(t+1)] - \cos[\ln(t+1)]\} + \delta_{2s}(t+1)\cos[\ln(t+1)]$$

The pre-test was measured in the first day and the post-test was measured in the final day, amount 30 marks respectively.

3.5 Data Collection

Data were analyzed by mean, standard deviation, and *t*-test dependent.

4. Results

4.1 To design a learning strategy for critical thinking skills development on analytical mathematical modeling of mechanical system

Students were synthesized the 12 article journal related from electronic database for example: sciencedirect and IEEE transaction. Researchers were measured by formative test through between kinematic modeling and dynamic modeling by eliminating the relative motion as shown in Table 1.

Table 1 Synthesis of CNC control with NHMS

Themes	Mean	SD.	Ranking
1. New case	4.36	0.89	high
2. Retrieved case	4.19	1.73	high
3. solved case	4.03	1.91	high
4. tested case	3.94	2.15	high
5. learned case	3.84	2.43	high

The results showed that the mean score all aspects were at high level. As a result, this research was also some suggestions of use learning strategy, that support students' thinking and reasoning respectively. Researchers were accepted this result to conduct one group pre-test and post-test namely Case-Based Reasoning Instructional Design (CBRIS) as shown in Figure 1.

4.2 To compare the learning achievement pre-test and post-test through a learning strategy for critical thinking skills development on analytical mathematical modeling of mechanical system

Table 2 The *t*-test dependent of learning Achievement

Score	Mean	SD.	*t*	df	Sig
Pre-test	16.16	9.31	-12.58	30	.000*
Post-test	24.87	5.69			

*P ≤. 05

In Table 2, the post-test mean score was higher than pre-test with the statistically significance difference at .05.

5. Discussion

Conducting experimental studies in this study is improving the instructional strategy for industrial technology education because they allow studying 'thinking like practitioners' in potential new learning innovations. Their ability was to solve problems and to establish whether CBRIS enhances it. This study both included an analytical reasoning approach and a previous experience. The fact there was a substantial treatment effect CBRIS, although, CBRIS is a new dimensions of learning-instructional strategy, it is a present one: enhances students' ability to solve engineering problems.

The finding was consequently CBRIS design was often taught as a set of procedures accompanied by simple examples and experiment in laboratories. CBRIS has more recently emerged as a conceptualized to bridge this gap between theory and practice in instructional design education [6], [7], [11].

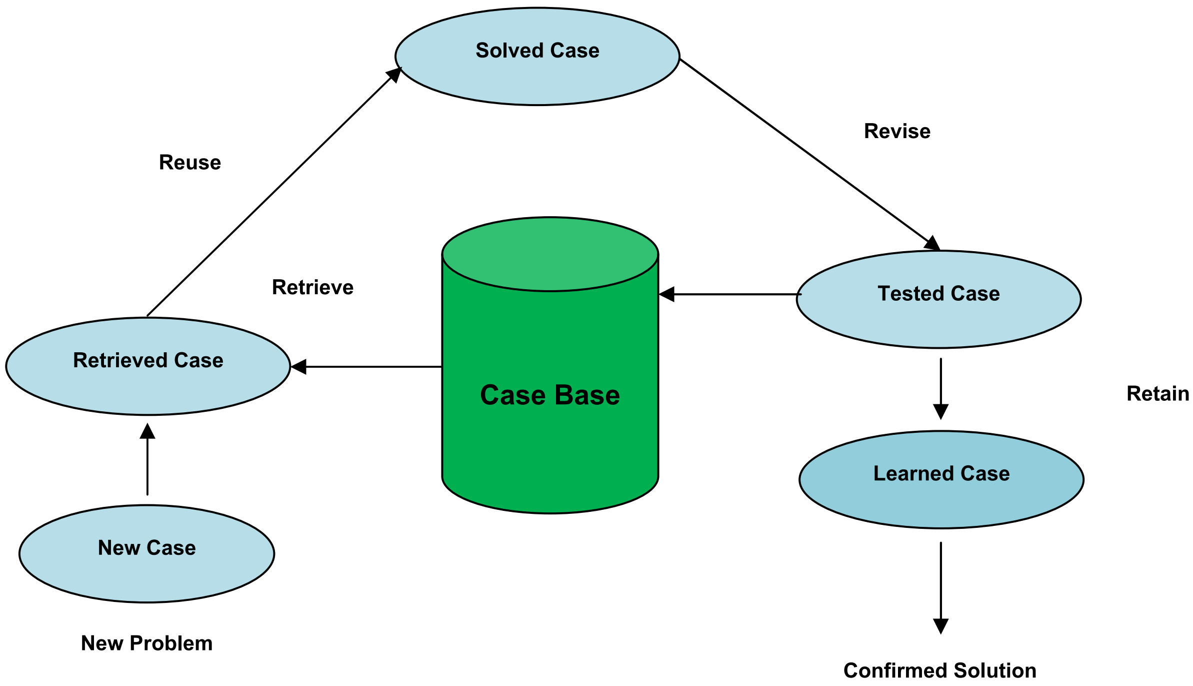

Figure 1 The CBRIS Model

Moreover, using the past experience might also be constructed when coming to understand the new situation, causing a case to be 're-indexed' [9]. Then, CBR is suitable to conduct in the study that considered a 'natural' form of students' reasoning, their prior knowledge to make sense of new situations [10], [13], [22], [23].

Sudsomboon [17] have shown that, an application of a CBR to teach analysis of non-holonomic mechanical (NHM) systems. In this study, the key challenge of teaching a class of dynamic systems arises from the fact which considers the problem. Both 5592103 Machine Design I and 5594111 Machine Elements courses at Mechanical Technology Program, Nakhon Si Thammarat Rajabhat University applies CBR into the motion of a plane NHM, consisting of two point masses, which move in such a way [23].

CBR describes as a constructivist teaching consists of systematic process: retrieve, reuse, revise and retain is investigated. This instructional strategy made enhance of their students' thinking by the inclusions of NHM idea benefits students, who are able to solve the equations of the constraints of such a system, are derived.

The content should be added the block diagram representation and introduction to control system. Finally, the real world situation did better on the employ of the strengths of CBRIS model. Other methodology of problem solving, such as authentic assessment of the solution and computer simulation and its feasibility, did use to conduct for completely results context; therefore, the means were better in the whole aspects [4], [5], [13].

The role of the students was to

- Students define and analyze the problem chosen for learning as new problem through index assignment;
- Students retrieved case with generate ideas incorporate situation knowledge. Then, Knowledge system model representation is identifying the rotational mechanical systems with configuration form;
- Students require analytical and reflective skills to derive the mathematical modeling and analysis of rotational mechanical systems and solved case as a reuse step and research their learning objectives. Students were gather information for solving problem from textbook, article journal in related field, group discussion;
- Students report back, synthesize explanations and apply newly acquired information to the problem for tested case as a revise step to

derive state equation, transfer function and analysis of system response; and

- Students' combine content knowledge and strategic thinking as thinking practitioners' as a retain step. The reiterative CBRIS also encouraged students and facilitators to evaluate the process and outcome of the CBRIS experience through students' communication and interpersonal skills. The solutions from expert will be showed and researcher is discussed and recommended.

On completion of CBRIS process, a post-test of students' approaches to learning was conducted using as same as the rotational mechanical system with deep and surface approach scales.

5. Conclusion

The outcomes of this study suggest that a case-based reasoning instructional strategy that supports the senior level of undergraduate mechanical technology students of Mechanical Technology Program, Faculty of Industrial Technology at Nakhon Si Thammarat Rajabhat University was conducted prior to the commencement of mathematical modeling of mechanical systems. For accomplishment in the research, a pre-test and post-test of their approaches to learning have been employed.

The appropriate implication was enhanced students' learning outcomes to encourage students to adopt an appropriate approach or to discourage them from adopting an inappropriate approach to learning. Furthermore, the CBIS model developed an understanding of the learning innovation of instructional strategy practice and was able to provide use of that knowledge to solve their students' performance.

References

[1] K. Ogata, ***System dynamics,*** 3rd ed., Pearson Prentice Hall, 2004.

[2] D. H. Jonassen, "Designing constructivist learning environment," In C. M. Reigeluth (Ed.). ***Instructional-design theories and models: A new paradigm of instructional theory,*** Vol. 2, (pp. 215-239), Lawrence Erlbaum, 1999.

[3] M. J. Hannafin, and S. M. Land, "Technology and student-centered learning in higher education: Issues and practices," ***Journal of Computing in Higher Education,*** Vol. 12, no. 1, pp. 3-30, 2000.

[4] W. Sudsomboon and A. Anmanatrakul, "Innovative of an Instructional Design for Thai Industrial Education through Case-Based Reasoning," ***Journal of King Mongkut's University of Technology North Bangkok***, Vol. 20, no. 3, pp. 620-632, 2010.

[5] W. Sudsomboon and T. Maungmungkun, "Integrating Case-Based Reasoning Approach in an Undergraduate Industrial Technology Research Course," in ***Proceedings of the 6th International Conference on Educational Reform (ICER 2013),*** Sokha Angkor Resort, Siem Reap, Cambodia, pp. 220-226. February 23-24, 2013.

[6] J. Kolodner, ***Case-Based Reasoning***, Morgan Kaufmann, 1996.

[7] A. Aamodt and E. Plaza, "Case-Based reasoning: Foundational issues, methodological variations, and system approaches," ***Artificial Intelligence Communications,*** Vol. 7, no. 1, pp. 39-52, 1994.

[8] C. Vong and P. Won, "Case-based adaptation for automotive engine electronic control unit calibration," ***Expert Systems with Applications,*** Vol. 37, no. 4, pp. 3184–3194, 2010.

[9] P. A. Ertmer and J. Quinn, ***The ID CaseBook: Case studies in instructional design,*** Prentice Hall, 2007.

[10] J. L. Kolodner, J. N. Owensby, and M. Guzdial, Case-based learning aids. In D. H. Jonassen (Ed.), ***Handbook of research on educational communications and technology,*** (pp. 329-861), L. Erlbaum Associates, 2004.

[11] R. Schank, ***Tell me a story: Narrative and intelligence,*** Northwestern University Press, 1990.

[12] D. H. Jonassen and J. Hernandez-Serrano, "Case-based reasoning and instructional design: Using stories to support problem solving," ***Educational Technology Research and Development,*** Vol. 50, no. 2, pp. 65-77, 2002.

[13] W. Sudsomboon, "Effects of a Computer-Based Concept-Mapping: The Learning Innovation in Industrial Education," ***Technical Education Journal of King Mongkut's University of Technology North Bangkok,*** Vol. 2, no. 2, pp. 11-19, 2011.

[14] P. A. Ertmer and J. D. Russell, "Using case studies to enhance instructional design Education," ***Educational Technology,*** Vol. 35, no. 4, pp. 23-31, 1995.

[15] D. H. Jonassen, "Toward a design theory of problem solving," ***Educational Technology Research and Development,*** Vol. 48, no. 4, pp. 63-85, 2000.

[16] D. H. Jonassen, "Typology of case-based learning: The content, form and function of cases," ***Educational Technology,*** Vol. 46, no. 4, pp. 11-15, 2006.

[17] W. Sudsomboon, "Applying Case-Based Reasoning to Teach Analysis of Non-Holonomic Mechanical Systems," in ***Proceedings of the 3rd International Conference on Sciences and Social Sciences (ICSSS 2013),*** Rajabhat Maha Sarakham University, Maha Sarakham, Thailand, pp. 17-25, July 18-19, 2013.

[18] C. M. Roithmayr, and D. H. Hodges, " Forces associated with non-linear non-holonomic constraint Equations," ***International Journal of Non-Linear Mechanics,*** Vol. 45, pp. 357-369, 2010.

[19] Xi. J. Tan, and Y. Wang, "Integrated task planning and control for mobile manipulators. ***International Journal of Robotics Research,*** Vol. 22, No. 5, pp. 337–354, 2003.

[20] C. Tang, P. Miller, V. Krovi, J. Ryu, J. and S. Agrawal, (August, 2011), "Differential flatness-based planning and control of a wheeled mobile manipulator—Theory and experiment," ***IEEE/ASME Trans. Mechatronics,*** Vol. 16, No. 4, pp. 768–773, 2011.

[21] L. Xiao, and Y. Zhang, (March, 2013), "A New Performance Index for the Repetitive Motion of Mobile Manipulators," ***IEEE Transactions on Cybernetics,*** DOI: 10.1109/TCYB.2013.2253461.

[22] W. Sudsomboon, "The Effects of Problem Solving Skills Strategy on Automotive Mechatronic Systems for Undergraduate Mechanical Technology Students," ***Technical Education Journal of King Mongkut's University of Technology North Bangkok,*** Vol. 2, no. 2, pp. 11-19, 2014.

[23] W. Sudsomboon, "Effects of an Inquiry-Based Learning Environment on Students' Achievement for Machine Design I Course," ***Technical Education Journal of King Mongkut's University of Technology North Bangkok,*** Vol. 2, no. 2, pp. 11-19, 2015.