Experienced and Inexperienced Students Research How to Evolve A Practical Chem-E-Car Project

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Abstract

The purpose of this study was to understand the differences of the creativity, capability of creative design, and problem-solving process between an experienced and an inexperienced groups of students who participated to build up a Chem-E-Car as a practical work project. The evaluation was done by using of anecdote records, observation records from teachers, experimental records, oral reports, and results of the works from an authentic performance evaluation. Each group had to design a special chemical-energy car using cooperative learning, and solve problems such as car body, the transmission system, chemical energy, and stopping on a given distance with a given load. The experienced students showed that they completely understood the basic theories and skills relating to the course of the work project, and saved lots of time achieving their goals. Obviously, the practical subject in the course of the work project make students understand better with cooperative learning, and help them solve practical problems which they may encounter in the future.

Key words：Chem-E-Car, problem-solving, authentic performance evaluation, work project

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有經驗與無經驗學生製作化學動力車實務專題之探討

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摘要

本研究的目的是想瞭解有經驗與無經驗組的學生在實務專題化學動力車製作時，他們的創造力、創意設計、及解決問題的過程與能力，本研究使用眞實的實作評量中的軼事記錄、老師的觀察記錄、實驗記錄、口頭報告、及製作成品來瞭解學生們的創造力、創意設計、及解決問題的過程與能力，兩組同學皆以合作學習的方式設計一台具化學動力的小車，他們必須解決車身、傳動系統、化學動能、及載重時必須停於一定的距離等問題，有經驗組的同學能完全瞭解此實務專題中的基本原理與技能，並且花費很少的時間即能達成他們的目標，顯而易見的，專題題目如果是實務性的題目，更易達成合作學習的目標，並且更能幫助同學瞭解未來遇到實務問題的解決方法。

關鍵字：化學動力車、問題解決、眞實的實作評量、實務專題。

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I. Introduction

In the years 2002 and 2003, the Chinese Institute of Chemical Engineering held initial Chem-E-Car competitions in Taiwan. Researcher led a group of students while they attended each of the Chem-E-Car competitions and thought that this practical project of Chem-E-Car was a meaningful educational experience; students also learned a lot from these competitions. It was worth of investigating the creativity, the creative design, and the problem-solving skill and capability of students from the project. Therefore, researcher wanted to conduct a survey in understanding the creativity, the ability of creative design, and the problem-solving process and ability of students in cooperative learning by doing this practical work project by technology-institute students.

The object of this competition was to design and construct a car that is powered with a chemical energy source which will carry a load to reach a given distance, and then stop. Before the competition, each team had to submit a written description for the car, which would include chemical energy sources, characteristics, net weight, and environmental and safety considerations. If obvious safety violations would occur, the judges would use their discretion in disqualifying the entry. The required load and distance were announced to the teams one-hour prior to the start of the performance competition. The distance was 15, 20, 25, and 30 m, and the load was 100, 200, 300, 400, and 500 ml water, respectively. The course was wedge shaped at the starting point, while the prescribed distance clearly marked with an arc of constant distance from the starting point. The winner will be the owner of the car which is the closest to the given distance. A vehicle that goes outside the course will fail for this trial.

Rules and requirements for the performance competition:

1. The only energy source for the propulsion of the car is due to a chemical reaction. Commercial batteries are not allowed as the power source.
2. The car must be an autonomous vehicle and cannot be controlled remotely.
3. No mechanical force can be applied to the wheel or ground to slow or stop the car.
4. There can be no mechanical or electronic timing device to terminate the chemical reaction.
5. All components of the car must fit into a shoebox with dimensions equal to or smaller than 32*20*12 cm.

6. The car must carry a container that holds up to 500 ml of water without spilling. This water container does not count as a component of the car.
7. The cost of the car and the chemicals used must be less than 15,000 NT dollars.
8. Students are responsible for transportation of the chemicals and arranging for the disposal of their chemicals and wastes. If students violate the industrial safety rules, the judges can disqualify their entry.
9. All cars must safely operate inside a building. (Chinese Institute of Chemical Engineering, 2002)[1]

II. Characteristics of Practical Work Project

Hsiao (1997) stated that students would integrate the basic theories and skills by the course of the work project and use their imagination and creativity to design the industrial products. In the meantime, students would learn problem-solving skill, team cooperation, human relationship, and skills from the course of the work project. [2]

1. Topic's Selection and Operational Style of the Work Project

The teaching goals of the course were to combine together basic theories, manufacturing, experiments, and the process of testing. This course tried to raise the capabilities of thinking, creation, and practicing skills of the students; it also provided the combination of theories and practicalities, as well as interchanged the professional knowledge and technology for students and advisor. This kind of teaching activity is boundless and is beyond other courses; the result is exciting. Students and teacher will not forget the learning process of having a combination of different courses and creative experiences with such technology (Ruan, 1993). [3]

Technological education enriches the experience of students in doing things by themselves, emphasizes on the course of work projects, intensifies students' creative thinking and problem-solving capability, improves the teaching quality of instructors that are teaching professional courses, and either improves the teaching environment. The teaching quality of the course will then be improved and the goal of technological education will be achieved definitely (Lee & Wang, 1998). [4] The property of such a work project integrates the content of courses. After students have learned professional theories and practical skills, they learn how to do organizing, integrating, applying, creating, and researching from the course of a work project (Hsiao, Zhao, & Hu, 1997). [5]

Guo & Zou (1997) thought that the teaching objectives of the course should be based on academic theory and go through the process of manufacturing, experimenting, and testing, in order to make students understand the developing design of products and the process of manufacturing. [6] This course also raises students' practical experiences and independent creative ability, giving students lots of professional skills in fulfilling the aim of the course. Therefore, this course provides teamwork and collects the intelligence of only a few students to complete it, and the work project is totally different from a traditional course, in which the student is working alone (Hsiao, Chang, & Huang, 2000). [7]

2. Evaluation of the Work project

Traditional teaching evaluation emphasizes on a written test, which only records the learning results of students for a certain period. A written test cannot let us understand the learning process of students, and also lacks the spirit of suitability, individuality, and diversity (Guo, 2001). [8]The work project is authentic works of the real life; hence, the authentic and performance assessments are appropriately used to evaluate the course of work projects. The performance and authentic assessments have many things in common; sometimes it is hard to distinguish between them. Some scholars will use them together as the authentic performance evaluation (Chang & Huang, 2000). [9]

After students finish their projects, the performance evaluation records the detailed problem-solving processes of students and makes them understand the progress of their inference (Garcia & Pearson, 1994). [10] Lin (2000) stated that the performance evaluation is a real situation, in which students must attend and operate by themselves, do problem-solving, and finish projects alone or in group-working sessions. Teachers with an objective evaluation method will aim directly at the operating process in evaluating their performance. Therefore, the style of a work could be a report, a composition, a speech, or an experiment. [11]

The advantages of practicing a performance evaluation are: (a) it is not only testing what students have learned but also tests what students can apply what they learned; (b) it can efficiently test the high-level proficiency of students in thinking analysis, research, and judgments; (c) it can offer a deep view in the thinking process and learning styles of students, find the differences of students' learning capability, and provide those results to improve teachers' teaching skill; (d) it makes students understand the importance and practicality of learning from the practical topic (Peng, 1996). [12] The performance evaluation is better used in evaluating the important technology and the concept of teaching. Designers of performance evaluation can observe the process or the results, or the process and results together as the main goal. In science competition, results are better than process in being the main goal of observation (Zou, 1998). [13]

The objective of the authentic evaluation is to help students understand how they should face, deal, and fulfill the work of the real life in a certain area. These activities in a work project include a broad area, such as anecdotes records, observing notes of teachers, discussions from students and teachers, and result of the projects, etc. The field of natural science includes experimental reports, scientific notes, reports of work projects, oral reports, etc. (Calfee & Hiebert, 1991). [14] Chan (1998) thought the best merit of authentic evaluation is to help teachers to record the important information of students' learning detailedly, (a) their experiences and manner before learning, (b) their learning process, (c) their difficulties in learning, and (d) the learning results, etc. All of this information can be recorded and understood by teachers through the authentic evaluation. [15]

The technology of authentic evaluation emphasizes an informal evaluating way, such as pure observation, involved observation, anecdotes records, diary records, interview, sampling records, timing sampling records, events sampling records, check lists, taking pictures, recording, videotaping, etc. (Muri & Wells, 1983). [16]

III. Methodology

The purpose of this study was to understand the process and differences of creativity, creative design, and the problem-solving process and ability using cooperative learning of the technological engineering students, whether with or without experience.

1. Sample： The first-year group (abbreviation as G1) was comprised of four college students. The second-year group (abbreviation as G2) was comprised of five college students, which were two experienced students of the first-year group and three college students. The first-year group (G1) is the inexperienced group and the second-year group (G2) is the experienced group. All students are majoring in chemical engineering in the Hsiuping Institute of Technology in

Taiwan.

2. Instrumentation：Anecdote records, observation records from teachers, experimental records, oral reports, and the result of the project's authentic performance evaluation was used to understand creativity, creative design, and the problem-solving process and ability of students.

IV. Data Collection and Analysis

The manufacturing of a Chem-E-Car was comprised of the following five items. 1. The body's choice and combination of the Chem-E-Car. 2. Choices of the transmission system of the Chem-E-Car. 3. Choices of chemical energy for the Chem-E-Car. 4. How to obtain enough power for the Chem-E-Car. 5. How to stop the Chem-E-Car on a given distance with a given load. Researcher followed these five items for data collection and analysis.

Item 1：The body's choice and combination of the Chem-E-Car.

G1 group (the first year): In the beginning students wanted to use the small body of the remote car for the body of the Chem-E-Car. After a long discussion, they realized they had to find and combine the body by themselves. They wanted to save some expenses and decided to be creative. They went to the recycled field and found a used wooden plank and some used wheels. They cut the wooden plank into a rectangle shape and connected the used wheels under it. They spent six weeks making it. The weight of the car was about 1000g.

It involves using the mechanical system in connecting the body and wheels of the car together. Chemical engineering students are not familiar with the mechanical system. Fortunately the father of one student is familiar with the mechanical system and is under the assistance of this student's father, so they can finish the job of combining the body and the wheels of the car together.

G2 group (the second year): Students had more experience in making the car's body. They realized the body type was good enough, so they did not want to change it. They decided to find a more firm and shining material to be the car's body, however, they combined an aluminum plank and four new wheels to finish the complete body of the Chem-E-Car. The weight of the car was about 950g, and they only spent two weeks in making it.

Item 2：Choices of the transmission system of the Chem-E-Car.

G1 group (the first year): Students wanted to save some expenses, so that they utilized a used motor (24 volts) and transmission belt. After the marching test of the Chem-E-Car, they found that the transmission belt did not have enough power to drive the car. If the field had a tiny obliquity or a small obstacle (for example: a feather), the car stopped moving. Therefore, they had to buy a transmission gear to replace the transmission belt, after the marching test of the car would run smoothly. The car would not stop, even if the field had a tiny obliquity or a small obstacle. The transmission system of the first-year car was a 24-volts motor with a transmission gear.

G2 group (the second year): Students found that the voltage of the 24-volts motor is too high for the car. If they wanted to drive the motor, they needed a series of many chemical energy cells. If they chose a low voltage motor (for example: 6-volts motor), the low voltage motor could not drive the car loaded with 500g of water. Therefore, students chose to buy a 12-volts motor which needed less chemical energy cells than the 24-volts motor. The 12-volts motor could either drive the car loaded with 500g of water. After having experience from the first-year job, they knew the transmission gear would be better than a transmission belt. Hence, the transmission system of the second-year car was a 12-volts motor and a transmission gear.

Item 3：Choices of chemical energy for the Chem-E-Car.

G1 group (the first year): The weight was almost 1000g, and the motor was 24 volts for the first-year car. In addition, the car should have had the ability to march to 30 meters. Therefore, they needed a chemical energy cell which had a higher voltage. From information inquiring and discussion, students decided to choose the Mg-Cu cell as the chemical energy. The Mg-Cu cell did not violate the rules and requirements of the Chem-E-Car competition, and the theoretic voltage of the Mg-Cu cell is 2.697volts (Fine & Beall, 1990). [17] Because the Mg-Cu cell has high voltage, series of less Mg-Cu cells could drive the car. The reaction of the Mg-Cu cell is as follows:

$$Mg_{(s)} + Cu^{2+}_{(aq)} \rightarrow Mg^{2+}_{(aq)} + Cu_{(s)}$$

Generally, the chemical energy cell needs salt-bridge to connect the anode and cathode reaction, thus, letting the chemical energy cell occupy more space. With the cellophane replacing salt-bridge, it will decrease half the cell volume. They used one 50ml beaker as a chemical energy cell (1M $CuSO_4$ solution was wrapped inside the cellophane membrane), and every beaker paralleled two Mg-Cu cells. The figure of one 50ml beaker Mg-Cu cell is shown in Fig.1.

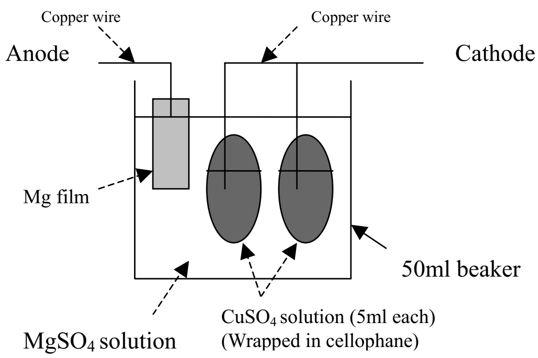


Fig. 1. One 50ml-Beaker Mg-Cu Cell

G2 group (the second year): Students had to wrap 24 $CuSO_4$ solution packages (series of 12 beakers) with cellophane for one marching test. It was time consuming to wrap 24 $CuSO_4$ solution packages. Thus, they decided to use a Mg-H_2 cell to replace the Mg-Cu cell. The Mg- H_2 cell also did not violate the rules and requirements of this competition, and the Mg-H_2 cell had various advantages, such as having high voltage, being cheap, and easy doing. The theoretic voltage of the Mg-H_2 cell is 2.360volts (Fine & Beall, 1990). [17]

The reaction of the Mg- H_2 cell is as follows:

$$Mg_{(s)} + 2H^+_{(aq)} \rightarrow Mg^{2+}_{(aq)} + H_{2\ (g)}$$

This Mg- H_2 cell also did not need salt-bridge to connect the anode and cathode reactions. One 50ml copper cup was used as a chemical energy cell (0.3M HCl was put inside the copper cup), and every cup paralleled with two Mg- H_2 cells. Students completely realized that it would increase and double the working electric current by paralleling two Mg- H_2 cells. The figure of one 50ml copper cup Mg- H_2 cell is shown in Fig.2.

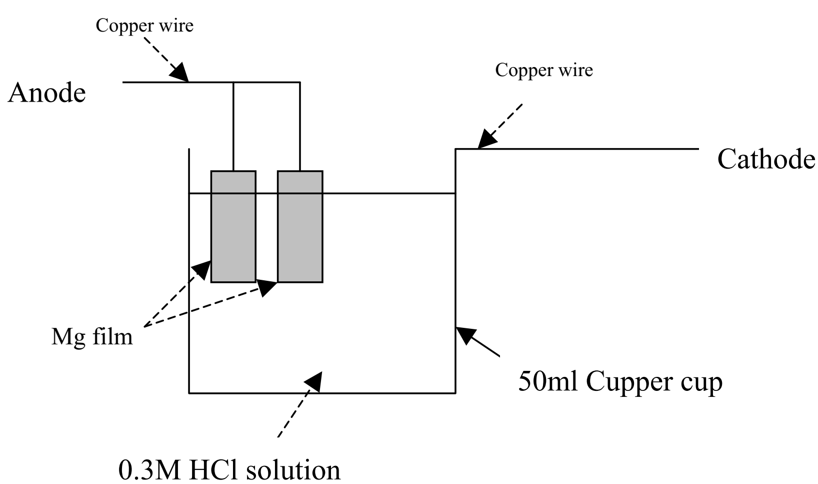


Fig. 2. One 50ml-Copper Cup Mg- H_2 Cell

Item 4：How to obtain enough power for the Chem-E-Car.

G1 group (the first year): A beaker of one Mg-Cu cell could not drive the car, until they put a series of 12 beakers of Mg-Cu cell together. The car could then move. The theoretical voltage of 12 Mg-Cu cells was 32.364 volts, but the operating voltage was only 8.0 volts, which were measured from the moving car. The car moved smoothly, but only when its operating voltage was about 8.0 volts. In a variety of grounds (marble, PU, and wooden grounds), the speed of the car was diverse. In general, the car's speed was 4 to 5 meters per minute with movement that was slightly unstable for unknown reasons.

They wanted to know the changes of electrolyte's concentration and how it could affect the operating voltage. They found the relationship between electrolyte's concentration and operating voltage as shown in Table 1. The operating voltage was measured when the car was moving during 5 meters.

Table 1

The Relationship of Electrolyte's Concentration and Operating Voltage

	Experimental State				
	1	2	3	4	5
$MgSO_4$	1.0M	0.8M	0.5M	1.0M	0.5M
$CuSO_4$	1.0M	0.8M	0.5M	0.5M	1.0M
Operating voltage (volt)	8.43	6.39	4.14	8.42	6.42

In No. 4 of the experimental state, the car was moving almost the same as No. 1 of experimental state, but the car apparently slowed down after moving 5 meters. In No. 2, 3, 5 of the experimental state, the car moved very slowly. Therefore, the electrolyte's concentration of $MgSO_4$ and $CuSO_4$ is 1.0M.

The chemical energy of the Chem-E-Car was a series of 12 beakers, and every beaker paralleled two Mg-Cu cells. The electrolyte's concentration of $MgSO_4$ and $CuSO_4$, therefore, is 1.0M. Students only considered the relationship of the voltage and the car's speed, even though they did not understand the relationship of the electric current and the car's speed. Thus, the speed of the first-year car was not very stable, they spent 12 weeks trying to find this result.

G2 group (the second year): One copper cup Mg- H_2 cell could not drive the car, until they used a series of 9 copper cups Mg- H_2 cells. Then the car could move. The car's speed varied in different ground with the car's speed being 4 to 5 meters per minute. Although the car's speed was almost the same as the first-year car, the second-year car moved steadily.

The chemical energy of the Chem-E-Car consisted of a series of 9 copper cups, and every cup paralleled with two Mg- H_2 cells. The overall operating voltage was 8 volts which was high enough to drive the car but found that the electrolyte's concentration of H^+ would affect the car's speed. The concentration of H^+ would not influence the operating voltage, but it would influence the electric current. When the electric current was lower than 350 mA, the car speed was

Table 2
The Relationship of H^+ Concentration and the Voltage(v) with Time Elapsing for One Mg- H_2 Cell

	H^+ Concentration		
Time (min)	0.10M	0.20M	0.30M
1	1.65	1.58	1.62
2	1.62	1.55	1.61
3	1.58	1.54	1.60
4	1.56	1.53	1.59
5	1.53	1.53	1.58
6	1.51	1.52	1.59
7	1.51	1.51	1.58
8	1.51	1.51	1.58
9	1.48	1.51	1.57
10	1.47	1.52	1.56
11	1.46	1.51	1.56
12	1.45	1.51	1.56
13	1.45	1.51	1.55
14	1.44	1.52	1.54
15	1.43	1.52	1.53

unstable, i.e., the car sometimes went fast and sometimes went slow. When the electric current was higher than 1000 mA, the motor could burn down. The relationship of the concentration of H^+ and the operating voltage with time elapsing for one Mg- H_2 cell within 15 minutes is shown in Table 2. As depicted in Table 2, different concentrations of H^+ only changed slightly in the operating voltage within 15 minutes for 0.30M H^+. They found the relationship of H^+ concentration (around 0.3M) and the electric current with time elapsing for one Mg- H_2 cell within 15 minutes as shown in Table 3 and Fig.3 using one Mg- H_2 cell. In regard to Table3 and Fig.3, the electric current should keep above 350 mA and below 1000 mA, allowing the car to move with stability. Within 7.5 minutes the car can move to 30 m (speed of the car was 4 to 5 m per minute), therefore, the electric current should stay slightly above 350 mA within 7.5 minutes. The concentrations of H^+ of 0.28M and 0.30M fit the requirements. For convenience, they chose 0.30M H^+ as the electrolyte.

The chemical energy of the Chem-E-Car consisted of a series of 9 copper cups and every cup paralleled with two Mg- H^+ cells, making the electrolyte's concentration of H^+ (HCl solution) be 0.3M. Students totally understood the influence of the voltage and electric current with the car's speed, as they spent 4 weeks in finding this result.

Item 5：How to stop the Chem-E-Car on a given distance with a given load.

G1 group (the first year) : In the beginning students wanted to stop the car by controlling the electrolyte's concentration of $MgSO_4$ and $CuSO_4$. In accordance with Table 1, changing the concentration of $MgSO_4$ and $CuSO_4$ decreases the operating voltage. The car does not have enough driving force to move; even if it could move, it would move without stability. Therefore, their idea was rejected.

Secondly, students decided to stop the car by controlling the electrolyte's volume of the $CuSO_4$ or the $MgSO_4$ solution. Shown in Fig.1, there was only a 5ml $CuSO_4$ solution wrapped in one cellophane package; it was hard to control minimal volume. Hence, they tried to stop the car by controlling the working volume of the $MgSO_4$ solution. The relationship of different volumes of $MgSO_4$ solutions and marching distances are shown in Table 4. If the volume of the $MgSO_4$ solution were lower than 10ml, the chemical cell would not work. If the volume of the $MgSO_4$ solution were higher than 40ml, the $MgSO_4$ solution would overflow from the 50ml beaker. Thus, the volume of $MgSO_4$

Table 3

The Relationship of H^+ Concentration and the Electric Current(mA) with Time Elapsing for One Mg- H_2 Cell

	H^+ Concentration					
Time (min)	0.24M	0.26M	0.28M	0.30M	0.32M	0.34M
0	720	740	900	920	1220	1200
1	660	680	850	850	1100	1100
2	590	620	750	780	1020	1000
3	540	550	680	700	920	890
4	430	460	620	620	850	710
5	405	420	550	550	730	580
6	380	385	455	450	600	410
7	340	350	405	400	470	300
8	295	315	360	340	395	245
9	255	285	290	300	340	205
10	215	255	250	230	295	165
11	185	205	215	195	245	140
12	130	160	190	170	210	110
13	100	130	160	150	180	85
14	95	105	115	130	150	60
15	85	80	95	115	115	40

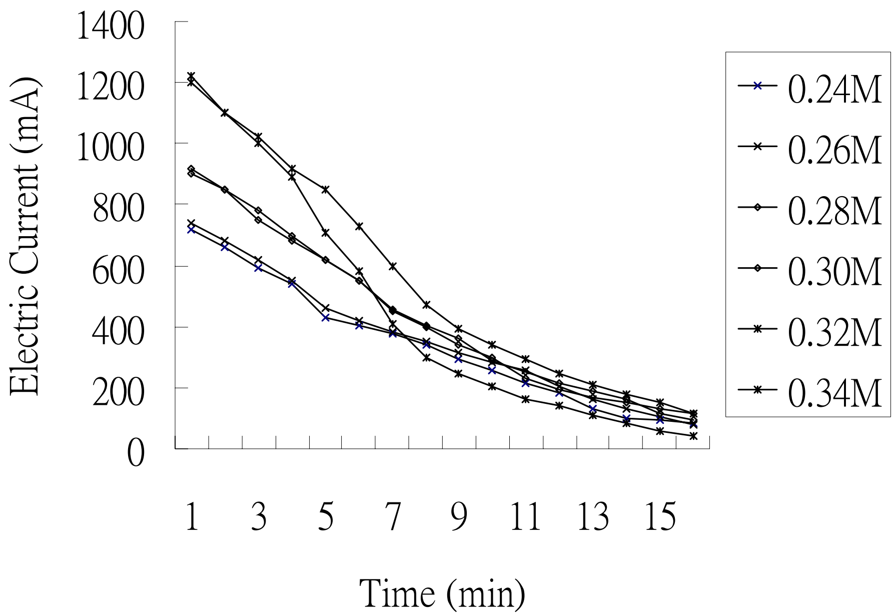


Fig.3 The Relationship of H^+ Concentration and the Electric Current(mA) with Time Elapsing

Table 4

The Relationship of Different Volume of $MgSO_4$ Solution and Marching Distance

$MgSO_4$ Volume	$CuSO_4$ Volume	Marching Distance (m)
40.0ml	5.0ml	Above 100
30.0ml	5.0ml	Above 100
20.0ml	5.0ml	96.03
10.0ml	5.0ml	51.30

solution should be controlled between 10 to 40ml. After some testing, they found the operating voltage of Mg-Cu cell slowly decreased. As depicted in Table 4, the marching distances were all above 30m, but the given distance of the Chem-E-Car competition was 15 to 30m. Hence, this idea was also rejected.

Thirdly, students wanted to replace the last one of the twelve series of beakers to be a controlling beaker, putting the Mg film into the HCl solution. The Mg film would break down after it reacts with the HCl solution, making the car stops immediately because of 12 beakers being connected together. The controlling beaker is shown in Fig.4 where a screw is locked with Mg film to add weight. Sometimes the Mg film is uneasy to break after it reacts with the HCl solution. If the screw was locked with Mg film, it would make the Mg film break easily. When students replaced the last of twelve beakers in series as a controlling beaker, the operating voltage of the car was almost the same, as with the 12 beakers that used Mg-Cu cells. The broken time of Mg film which reacted with different concentration HCl solution is shown in Table 5. The error of the broken time of Mg film was about 10% for the controlling beaker.

From the measurement of the velocity of the car and the given distance, students calculated the marching time, which contrasts with Table 5. They found out the key concentration of HCl, which they needed to put into the controlling beaker. Therefore, the controlling beaker, which put Mg film into the HCl solution, was a good way to stop the car on the given distance.Students spent 8 weeks in finding this result.

G2 group (the second year): Students continued to use the same idea as the first-year group, but they devoted to improve the broken time of the Mg film and make it more

Table 5

The Broken Time of Mg Film Which Reacted with Different Concentration of HCl Solution

HCl (M)	Broken Time of Mg Film（sec）
0.52	203.0
0.54	189.3
0.56	153.3
0.58	148.3
0.60	139.3
0.62	130.3
0.64	117.0
0.66	105.6
0.68	85.3
0.70	81.3

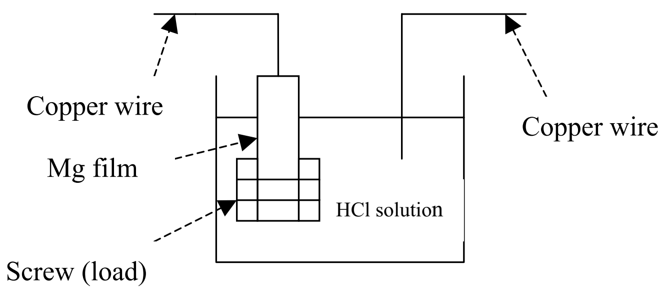


Fig.4. The Controlling Beaker

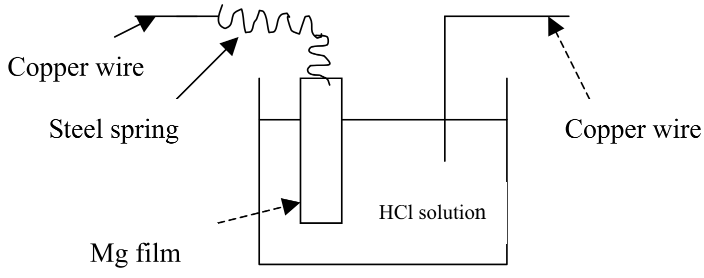


Fig.5. The New Controlling Beaker

accurately. The screw in the controlling beaker would lose its weight by reaction with the HCl solution; therefore, they had to use a new screw for every test, and it was very troublesome for them.

Furthermore, they had to find a new way to improve this condition. The new controlling beaker is shown in Fig.5 where the steel spring is connected to the Mg film. When the Mg film broke, the spring would shortly bring the residual Mg film out of the solution, suddenly cutting down the electric current. The error of the broken time of Mg film was about 5% in the new controlling beaker, which was more accurate than the first-year controlling beaker. Students spent 2 weeks in finding this result.

V. Findings and Discussion

Through this research we had several major findings and discussions.

1. Students improved their potential in creativity and creative design with cooperative learning. They made the Chem-E-Car a practical design, environmental and safety consideration, and marching stably. The figure of the complete Chem-E-Car set is shown in Fig.6.

The students knew each other for a long time, and they had shared the same interests. In the making-the-car period, they communicated and coordinated very well. Hence, the creativity and creative design were enforced by cooperative learning. This finding corroborates Skemp's (1991) beliefs: He thought students had interactive relations through the discussion of cooperative learning. He believed that this kind of discussion is helpful in stimulating new ideas and producing some creative results. [18]

2. The accuracy of the experienced students' car that stopped on the given distance was doubled than that of the inexperienced students' car.

Through making and testing the car in the second time, the experienced students realize the basic physical, chemical, and mechanical principles inside the Chem-E-Car much more than the inexperienced students. Therefore, the experienced students could make and test the car much faster than the inexperienced students. The experienced students redesigned the controlling system which made the car stop more precisely on the given distance.

3. The first-year car-making and competition limited the creative thinking of the experienced students. Therefore, the experienced students did not have more creative designs than the inexperienced students.

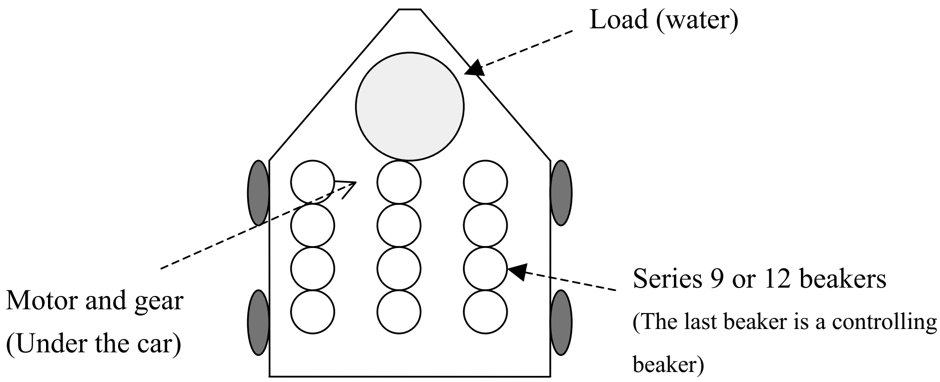
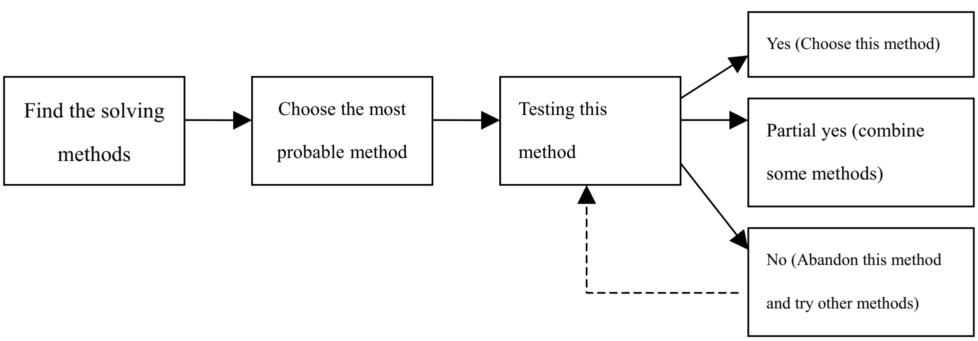


Fig.6. The Complete Chem-E-Car

Because the first-year car was not perfect, the experienced students decided to improve the defects of it. They also hoped to win the competition and did not want to make a lot of changes in their car.

4. Students found problems by themselves and followed the model of problem-solving to decipher problems. Their model of problem-solving is shown as follows:



Because the topic of work projects is practical, students discuss over and over again on how to confirm the source of problems and solve them. Naturally they follow the problem-solving model to decipher problems. This finding coincides with Hsiao's (1997) beliefs: He thought students could learn the ability of problem-solving, team cooperation, human relationship, and technology from the course of doing work projects.

5. The controlling system, which was the Mg film reacting with the HCl solution could stop the loading car on the given

distance accurately with the velocity of the car.

The ground of the competitive field could be varied material, as different ground had different friction. Therefore, data tested from one field could not fit for the other field. Thus, the car's velocity was tested in the competitive field, and the velocity multiplied the reaction time of the controlling system would be the given distance. Their Chem-E-Car moved slowly and with stability, hence, the car could easily be controlled and stop on the given distance quite accurately.

VI. Conclusions

1. The experienced students could thoroughly figure out basic theories and skills relating to the course of work projects, but the inexperienced students could only partly understand basic theories and skills relating to the course of work projects.
2. The experienced students were more efficient in making the Chem.-E-Car and more precise in stopping it on a given distance with a given load than were the inexperienced students.
3. The experienced students did not have more creative designs in their work project.
4. The practical and integrated topic of the work project, which operated with cooperative learning, reinforced students' creativity and their capability of creative design.
5. The work project, which applies to the real world, makes students clearly understand the problem-solving process and having the ability to decipher problems.
6. The work project, with a cooperative learning style, is appropriately evaluated with an authentic performance evaluation that helps us understand the operating process of a work project. No matter whether we use a process or results to be the evaluating standard, the grades of these two groups are excellent.

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