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USING ARCS MODEL TO PROMOTE 11TH GRADERS' MOTIVATION AND ACHIEVEMENT IN LEARNING ABOUT ACIDS AND BASES

ABSTRACT. The purposes of this study are: to apply the ARCS model in designing an acid and bases unit, and to assess a single class of 11th graders for motivation and achievement outcomes before and after ARCS instruction. Four essential strategies for designing motivation instruction in the ARCS model were: Attention, Relevance, Confidence, and Satisfaction. We used the ARCS model in designing a 10-hour acids and bases lesson for one class of 11th graders with low interest and motivation in chemistry learning. Both the Students' Motivation toward Science Learning questionnaire (SMTSL) (Tuan, Chin & Shieh, in press) and a teacher-designed achievement test were implemented before and after instruction. In addition, students' self-reporting on time engagement in learning before and during the instruction was also collected. The results of the study indicated that both students' motivation and achievement in the acids and bases unit increased significantly ($p < 0.05$) after the ARCS instruction. Students' time engagement during the ARCS lessons had increased from before. Findings of the study showed that using the ARCS model to teach acids and bases unit could improve low motivated students' level of motivation and achievement. The implications for chemistry teaching will be discussed in the paper.

KEY WORDS: ARCS instruction, chemistry learning, chemistry teaching, student's motivation

To design effective instruction, teachers must take students' learning motivation into consideration, because pupils learn only if they want to learn (Fairbrother, 2000). Fairbrother (2000) indicated that student motivation is the single most important factor in raising standards of a national curriculum. But the educational reforms of the past years have concentrated more on both changing the organization and structure of the educational system and on attempting to improve the quality of teaching and teaching materials. Few efforts have addressed helping students promote their motivation for learning. Motivation refers to a student's willingness, need, desire and compulsion to participate in learning, and to be successful in the learning process. Addressing students' motivation can help students be involved in both classroom activities and concept understanding (Bomia, Beluzo, Demeester, Elander, Johnson & Sheldon, 1997). The researchers (Barlia & Beeth, 1999; Pintrich, Marx & Boyle, 1993) pointed out that students'

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motivation is an important factor that can lead to raising or lowering the status of students' level of concepts.

Zoller (1999) stated that traditional chemistry teaching relies heavily on lecturing. In the lecture environment, students use a passive approach in learning chemistry. Gabel (1999) surmised that the primary barrier in understanding chemistry is that chemistry instruction occurs predominantly on the abstract and symbolic level. It is hard to increase students' motivation only by conveying the threefold sub-micro, macro, and symbolic dimensions of chemistry with students. Learning is not just to understand and as researchers (Barlia & Beeth, 1999; Fairbrother, 2000) have mentioned, there are a numbers of factors that affect a pupil's ability to respond and learn from classroom teaching. The motivational aspect of learning can not only assist pupil's learning, but can also provide them with a set of skills which will benefit their lifelong learning (Fairbrother, 2000). Thus, in order to help students learn chemistry, one direction might be to promote instruction based on students' motivation rather than their cognition.

Although traditional teaching also emphasizes increasinging students' motivation initially, it is more important to sustain learning motivation during the teaching process. The teaching process should be seen as a motivational process and cannot be looked at in isolation (Visser, Plomp & Kuiper, 1999). Recently, research on motivation has focused on the identification of effective techniques for enhancing instructional design and improving classroom management (Small, 1997). Among the various models, the ARCS model (Keller, 1983) has been considered a systematic and easy-to-apply model for designing motivational instruction (Shellnut, Knowlton & Savage, 1999; Small, 1997; Song & Keller, 1999).

The purposes of the study are: applying ARCS the model to designing an acids and bases unit, and assessing the students' motivation and achievement after learning the acid and bases unit.

LITERATURE REVIEW

From high school to the university chemistry curriculum, the topic of acids, bases and pH is considered a challenging topic for students to understand (Nakhleh & Krajcik, 1994; Zoller, 1990). This, in turn, has led to the creation of several different teaching models to address the concepts of acids and bases, such as: including various learning technologies (Nakhleh & Krajcik, 1994), integrating multiple teaching methods (Francisco, Nicoll & Trautmann, 1998), and emphasizing epistemological reasoning (Erduran, 1999). Students' motivation is also an important component of learning from a constructivist viewpoint, but research in this area has been relatively sparse.

Traditional chemistry lectures consist of presenting facts, formulas and problem solving. Students took notes and tried to comprehend the nature, rather than abstract concepts, of chemistry (Folino, 2001). The cognitive variable is only one of the variables that influence learning. There are many other elements comprising the social and emotional context in which the learning task is located (Hodson, 1998). Though the theory and research about motivation have generated many disputed areas, Hodson (1998) concluded that there is an emerging consensus on which teachers can draw. Hodson (1998) presented Vroom's two suggestions for curriculum intervention. The first is to provide a curriculum that students valued. The second is to raise students' expectancy levels by ensuring that everyone experiences successful learning. Keller's ARCS model is rooted in Vroom's notable expectancy-value theory (Keller, 1983; Small, 1997; Vroom, 1964). In this theory, "effort" is identified as the major measurable motivational outcome. For effort to occur two necessary prerequisites are specified: (1) the person must value the task and (2) the person must believe he or she can succeed in the task (Hodson, 1998; Small, 1997). Therefore, in an instructional situation, teachers can create learning environments to stimulate and sustain motivation, even though they do not have to fully control it. The learning task needs to be presented in a way that is engaging and meaningful to the students, and in a way that promotes positive expectations for the successful achievement of learning objectives.

The ARCS model (Keller, 1983) identifies four essential strategies for motivation instruction:

(1) The Attention strategy is for arousing and sustaining curiosity and interest.
(2) The Relevance strategy is to link learners' needs, interests, and motives.
(3) The Confidence strategy is to help students develop a positive expectation for successful achievement.
(4) The Satisfaction strategy is to provide extrinsic and intrinsic reinforcement for effort.

The ARCS model provides a basis for designing teaching activities that support teachers in the development of a motivational curriculum. As Keller (1987) pointed out the real challenge is to help students sustain their learning so as to produce a satisfactory level of attention throughout a period of instruction. Keller (1987) also emphasized 'relevance' as a powerful factor in determining what students are motivated to learn or why they are willing to continue with their attention fixed on learning tasks. From a design point of view, the ARCS model presents the requirements for a set of learning activities needed to to increase students' learning motivation. The hypothesis embodied by the ARCS model is that a designer can achieve a learning objective more effectively if they follow the four design steps in the ARCS. Keller (1987) added different processing questions and motivational strategies that can fulfill the requirements of each step.

The ARCS model has been useful for developing computer-assisted instruction (Keller, 1997; Shellnut, Knowlton & Savage, 1999; Song & Keller, 1999). Shellnut (1999) found that confidence and satisfaction have the most impact on the perceived success of instruction. But, Arnone & Small (1995) and Small, Dodge & Jiang (1996) recognized that without learners' 'attention' and interest, there could be no potential for 'relevance,' 'confidence,' and 'satisfaction' in the ARCS model. They reasoned that a lack of learner interest results in a failure to pay attention to instruction and none of the other motivations could be activated. Learners' interest, specifically curiosity, is perceived as a foundation of continuing motivation to learn. Shellnut (1999) and Small et al. (1996) agreed that motivation was the only variable that directly affected the instructional design. Nonetheless, Shellnut (1999) found designers appeared less likely to analyze students' motivation because motivation is a vague concept that is difficult to analyze systematically. Small et al. (1996) suggested motivational guidelines for the design of effective instruction should include attention getting instruction, incorporate surprise and use of instructional materials.

THE ARCS MODEL IN ACTION: THE ACIDS AND BASES LEARNING ACTIVITIES

Though the concepts of acids and bases are familiar in students' daily lives, teachers often present these concepts in an abstract way. Teaching acids and bases can use not only symbolized equations to engage students to learn. The ARCS model can be easily applied to design high interes tacids and bases learning activities, not just to help students understand but to help them want to understand. There are two major steps in designing an ARCS lesson, first, we use the ARCS framework in analyzing students' learning motivational states. Secondly, we designed the acids and bases learning activity using previous analysis of results.

Analysis of Students' Learning Motivation States

Using the ARCS model to design a lesson firstly needs analysis of the target audience and existing instructional materials, which can then provide guidance for creating and selecting motivational tactics. The learners' motivational status can be estimated based on the designer's personal experience, objective assessment from students, or both (Keller, 1987). The analysis (see Figure 1) of motivational needs and corresponding selection of tactics are based on the four dimensions of the ARCS model (Keller, 1999). Using the results of the analysis we can anticipate the obstacles and the consequences of failure of students to learn, and what student motivation status is.

Based on the analysis on Figure 1, factors that impeded students' motivation are: teacher-centered lectures, passive learners, materials and content being irrelevant to students, too few lab activities and test scores being the only reward for student learning effort. Below, we will describe how we designed the teaching for the ARCS based on the factors identified in Figure 1.

Design of the Acids and Bases Learning Activities

The fundamental concepts of acids and bases, such as those involved in the definition of acids and bases, reaction of acids and bases and the basic neutralization reaction have already been taught in the 10th Grade Chemistry I course. In the 11th Grade Chemistry II course, the unit "acids and bases" contains the following advanced topics: pH scales, self-ionization of water, measurement of pH, strengths of acids and bases, pH and life, temperature and pH, neutralization reaction, heat of neutralization, neutralization of strong acid and bases, titration of strong acid and bases, and the titration curve. We implemented the ARCS model on the acid and bases unit as follows:

Attention

In the previous section, the problem of student attention arose due to teacher-centered instruction neither arousing passive learners' interest and curiosity nor reducing student test anxiety. Therefore, in the 10-hour acids and bases unit, we created a learner-centered and cooperative learning environment. As Gabel (1998) has suggested, there is no one effective teaching strategy that leads to conceptual understanding, but a linking together of many strategies such as analogy, technology and lab instruction can enhance students' conceptual understanding. In addition, Brophy (1998) also addressed the importance of using various teaching strategies to arouse students' motivation. Thus, we incorporated multimedia and different kinds of activities that included relevant and inspiring graphics, animation and video.

Lab activities,which provide active ways of engaging students, have a beneficial effect by interesting and motivating students in chemistry les-

Attention	Relevance	Confidence	Satisfaction
♦ Traditional lecture is boring. Students like lab work. ♦ Teacher-led instruction makes students just listen. ♦ Lecture teaching cannot stimulate and increase students' curiosity. ♦ Singular presentation doesn't sustain students' interest. Students are passive learners. ♦ Learning activity is just listening and making notes.	♦ Chemistry content is away from students' learning experience. Most students are not familiar with chemical materials and concepts because the teacher doesn't provide concrete examples and analogies related to the learners' world. ♦ Students are knowledge receivers. Learning is to pass tests not to understand concepts. ♦ Having a high grade is the goal of learning. ♦ Students study only before the examination. ♦ Students like doing experiments because it is fun and they don't have to do it alone.	♦ Calculation is the most difficult learning task for students. ♦ Chemistry concepts are too complicate to learn. ♦ Students don't have trust and positive expectations for success. The criteria for success are only based on the test scores. ♦ Most students don't have a solid belief in competence and successful learning experiences. ♦ Students don't have the opportunity to receive feedback that attributes success to personal effort.	♦ Testing score is the only feedback and information that reinforces personal effort and accomplishment. ♦ Teacher usually uses verbal praise, scarcely lets learners present the results of their efforts to reward success. ♦ The performance requirements in the classroom are good behavior and high measured score for all learners' tasks and accomplishments.

Figure 1. Using ARCS model to analyze student's learning motivation states.

sons. We designed different types of acids and bases experiments to make learning activities more vivid. These experiments, unlike traditional demonstrations, are student-centered learning activities. During the lab activities, we constantly posed questions and encouraged students to find solutions for their own problems.

Relevance

Based on the previous section, students felt chemistry teaching is unrelated to their daily lives. Sisovic & Bojovic (1999) found that the relevance of science topics to daily life can influence students' motivation. Therefore, in our acids and bases unit, we provided concrete examples and analogies related to students' interests and experiences. We also showed students how acids and bases can be used in daily life. We provided lab investigation for students, so that they could actively engage in constructing their own knowledge. We also introduced our goals for the lessons and encouraged students to establish achievable goals for themselves.

Confidence

In Figure 1, students did not have confidence as to their success in chemistry learning. Therefore, we created an open and cooperative learning environment. Sisovic & Bojovic (1999) found that cooperative learning could increase students' self-respect and reduce competition anxiety. We carefully designed the learning tasks that were at an appropriately difficult level for students: gave timely and positive feedback to make them believe they could do well and provided students the opportunity to practise and acquire new skills under low-risk conditions. We also set appropriate expectations for students when completing assignments, giving presentations, conducting discussions, and taking tests. Appropriate expectations mean that teacher standards are high enough to motivate students to do their work but not too high so that students will inevitably be frustrated in trying to meet those expectations. In conducting lab activities, we aimed to teach the students important lab skills step by step first, so that they could build up confidence in conducting investigative activities.

Satisfaction

As seen in Figure 1, testing score is the only feedback for student learning outcomes. To build up student satisfaction in learning, there should be a focus on providing feedback and other information that reinforces positive feelings for personal effort and accomplishment. Throughout the learning activities we used – verbal praise, material or symbolic rewards, incentives and letting students present their results in front of classmates – to help students increase their satisfaction in relation to their learning performance.

We also used test score to increase student satisfaction. In order to reduce student test anxiety, we designed a cooperative test so that students could work together to complete the test. We also made performance requirements consistent with stated expectations, and provided consistent measurement standards for all learner tasks and accomplishments. Based on this kind of assessment, students could have the opportunity to get good grades and also to reduce their anxiety in taking tests.

METHODS

Participants

Participants were selected from a rural county public senior high school in the centre of Taiwan. Fifty-one 11th graders, which included 34 boys and 17 girls, participated in this study as an experimental class. We chose another class (35 boys and 15 girls), who were being taught with a traditional lecture teaching style, as a control class. All participants were enrolled in a Chemistry II program – they had taken a Chemistry I fundamental chemistry course in 10th grade. Chemistry II was designed for students who planned to major in science in college.

The first author, who is also the chemistry teacher for the participants in the study, taught lessons on acids and bases for both the control and experimental groups.

The Acids and Bases Learning Unit

Based on the above ARCS design rationale, in this 10 hour unit, we grouped 7–8 students according to their willingness to be together. Each group was provided with a worksheet with a specific task description, necessary equipment and materials. The worksheet included practical procedures and questions for students to be able to formulate and write down their observations, explanations, chemical equations, and conclusions. We established the environment that students needed to be actively involved in learning while being cooperative with their peers in the learning tasks. This kind of learning environment can meet the criteria for attention, relevance, confidence and satisfaction in the ARCS model. At the beginning of the lesson, we used lab activities and cognitive disequilibrium questions to arouse student attention. We also provided many lab activities for students to make science relevant to them. For the difficult concepts, we taught students step by step made sure they understood, and then increased the difficulty level of the problems. These methods can build up students' confidence levels. We asked students to present their responses in the class;

made competitive games; praised good efforts and so increased the satisfaction level in the class. Finally, we used a cooperative test at the end of each unit for students to be able to reduce test anxiety and to increase their confidence and satisfaction in their learning. Below, we will briefly discuss the teaching strategies used ineach unit:

Unit 1: The pH Scale
After reviewing the concepts of acids and bases, we provided eight samples, which including orange juice, milk, coffee, tea, coke, distilled water, vinegar, and soda water, to students. Students had to predict if each sample was acidic, basic or neutral, then test this out by using red and blue litmus papers. After arousing student interest, the teacher then introduced the more precise method of the pH scale to represent acidity and basicity. In teaching the difficult concept of the logarithmic value of (H^+), the teacher guided students step by step to find the value from a logarithmic table and ineach step in the calculation. Based on the above strategies, we could increase student confidence in learning PH calculations.

Unit 2: Self-Ionization of Water
In learning the self-ionization reaction of water, the teacher wrote down the reaction of self-ionization of water and posed the question to the students of, "What did we drink most of in a bottle of distilled water, H^+, OH^- or H^+?" After group discussion, students presented their thoughts to the class. This kind of question can arouse students' cognitive disequilibrium and increase their interest to learn. In addition, the teacher would stress the importance of the Kw concept to students by constantly addressing this concept.

Unit 3: Measurement of pH
Students were asked to test different pH solutions, by using flower and vegetable dyes instead of litmus as an acid/base indicator. This activity would not only get the attention of students, but also helps students find the relevance of the content to their daily lives. After a group presentation on the students' findings, the teacher chose the best result from each group and praised their good efforts. In case students could not find a good flower indicator, the teacher prepared red cabbage juice for students to use. This kind of supplementary activity can increase student satisfaction in learning.

Unit 4: Strengths of Acids and Bases
The teacher posed the question – "Is an HCl solution with a pH $= 6$ a strong or weak acid?", to arouse students' cognitive disequilibrium in

distinguishing between strong and weak acids. Students conducted lab activities to find an answer and then presented their results tothe class.

Unit 5: pH and Life

The teacher asked students what they knew about acids and bases, and found that most students could not recognize the uses of acids and bases. To improve students' understanding, and make science relevant to them, we linked in the information of pH from professions such as a pH meter – medical equipment, the acid rain of Taiwan, the pH requirement of different fish, and the pH of soil. These examples can help students relate pH to their daily lives, and also help them extend their knowledge of pH into other fields.

Unit 6: Temperature and pH

K_w is an equilibrium constant that varies with temperature. We used Le Chatelier's principle to establish a table to help students easily observe the change of K_w with increasing temperature. In this table we put in some blanks for students to fill in. This activity lowered the difficulty level of the K_w concept and improved student confidence in constructing the concepts.

Unit 7: Neutralization Reaction

To gain the students' attention and make the content relevant, we asked students why we use the juice of a Giant elephant's ear (traditional Chinese medicine) to cure the pain caused by the stinging nettle plant in Taiwan, as an example, and told students how to use a neutralization reaction in everyday life. We also provided lab activities for students to test the pH values of different types of solutions, so that they could distinguish the acids and bases in a non-equilibrium and equilibrium situation. At the end of this unit, we prepared a low concentration of a NaOH solution with a phenolphthalein indicator. We invited students to have a contest, so that whoever could quickly breathe and turn the the NaOH pink solution colorless, would be the winner. This game-like activity aimed to increase student satisfaction level.

Unit 8: Titration of Strong Acids and Bases

We used a video-tape to introduce the procedures and apparatus for titration to gain student attention. The teacher demonstrated the standard titration procedures and asked students to draw the titration curve while the teacher conducted a titration demonstration. Based on these step by step procedures, the teacher could discuss with students the meaning of the titration curve, and how to draw an accurate titration curve. Later, each group of students was required to determine the concentration of an unknown solution. The teacher praised the winner by giving them a small gift in front of the class.

Data Collection

At the beginning and at the end of the ARCS lessons, the Student Motivation Toward Science Learning questionnaire (SMTSL) (Tuan, Chin & Shieh, in press) and teacher-designed achievement tests were implemented for both the experimental and control groups. In addition, an open-ended questionnaire, which focused on students' self-evaluation of on-task time in chemistry learning, was implemented for the experimental group.

SMTSL is composed of 6 categories: self-efficacy, active learning strategy, science learning value, performance goal, achievement goal, and learning environment stimulation. The Cronbach alpha for the entire questionnaire was 0.89, and for each category, the scale ranged from 0.70 to 0.87. There were 35 items in the SMTSL with responses from strongly agree (5) to strongly disagree (1).

There were two different achievement tasks used in the study. The pre-test was developed for measuring students' basic acids and bases concepts, which they had previously learned in Chemistry I. An example of a test item is Item 2: "Acids can change litmus (a blue vegetable dye) from blue to (A) green (B) red (C) brown (D) yellow."

The post-test measured students' acids and bases achievement scores after taking ARCS instruction. This test contained 40 conceptual questions related to the 8 acids and bases advanced units addressed above. An example of a test item is Item 15: "Which compound can react with vinegar to form salts and water? (A) Citric acid (B) Carbonic acid (C) Ammonia water (D) Water."

RESULTS

Changes in Student Motivation

Table I contains the means and standard deviations of the pre-instruction SMTSL scores for the experimental class ($N = 51$) and control class ($N = 50$). Analysis of each motivation category revealed that the differences between the experimental and control classes did not show statistical significance for the pre-instruction stage. T-test analysis revealed that there was no significant difference between the experimental and control groups in their level of motivation for the pre-test results. However, there were significant differences for the six scales in the SMTSL between the experimental and control groups' post-test results (Table I). Based on the

TABLE I

Comparisons of students in experiment and control classes their motivation in pre-instruction and post-instruction

Motivation categories	Pre-test					Post-test				
	Experiment		Control			Experiment		Control		
	Mean	SD	Mean	SD	T	Mean	SD	Mean	SD	T
Self-efficacy	3.41	0.62	3.26	0.61	1.24	3.59	0.56	3.22	0.66	3.04**
Active learning strategy	3.82	0.47	3.71	0.51	1.12	3.93	0.44	3.62	0.59	3.02**
Science learning value	3.74	0.67	3.73	0.66	0.09	3.95	0.57	3.54	0.55	3.68***
Performance goal	2.23	0.65	2.49	0.74	−1.89	2.12	0.75	2.49	0.72	−2.55**
Achievement goal	3.93	0.56	3.92	0.60	0.14	3.93	0.67	3.66	0.52	2.26*
Learning environment stimulation	3.61	0.52	3.55	0.54	0.79	3.62	0.43	3.13	0.41	5.85***

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

above results, there is an indication that ARCS instruction for theacids and bases unit promoted student motivation in the experimental class in their learning.

Paired T-test comparisons, pre- and post-test for theexperimental group (Table II) indicated that students' motivation in self-efficacy, active learning strategy, and science learning value categories changed significantly ($p < 0.05$). Although the other two categories, performance goal, and achievement goal, decreased in the post-test there were no significant differences. Students perceived that the learning environment stimulation had been changed, but still did not show a significant difference.

Self-Efficacy

Self-efficacy means students have confidence in their ability to accomplish science learning. Students' self-efficacy was significantly promoted after learning the acids and bases units ($p < 0.01$). All means of the seven items in the self-efficacy category showed students to have a positive and increased rating. In Table III, Students' responses to items 3, 6, and 7 showed a statistically significant change ($p < 0.05$). These items mean

TABLE II

Comparisons of experimental class students' motivation between pre- and post-instruction

	Pre-test		Post-test		
Motivation categories	Mean	SD	Mean	SD	*T*
Self-efficacy	3.41	0.62	3.59	0.56	3.06**
Active learning strategy	3.82	0.47	3.93	0.44	2.01*
Science learning value	3.74	0.67	3.94	0.57	3.91***
Performance goal	2.23	0.65	2.12	0.75	−1.39
Achievement goal	3.93	0.56	3.93	0.67	−0.09
Learning environment stimulation	3.61	0.52	3.62	0.43	0.09

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

students increasingly confirm that they can do well on science tests, prefer to think for themselves, and would try to learn the difficult content. All these results showed students increased in their confidence tin being able to learn acids and bases concepts and in gaining good learning outcomes.

Active Learning Strategy
Active learning strategies mean students take an active role in using many different strategies to construct new knowledge from their previous understanding. Students significantly promoted their active learning strategy after they had learned the acids and bases units ($p < 0.05$). Their ratings of the eight items in the active learning strategy category have positive increases. In Table 3, the students' scores on items 8, 9, 10, 12, 15 show a statistically significant increase ($p < 0.05$). These items mean students attempted to understand new chemistry concepts and were able to connect them to their previous experiences. Students actively found relevant resources to help their understanding. Especially items 8, 9, 11, and 12 were rated above the scale of 4. These items represent students having more confidence in learning new science concepts, and the fact that they would attempt to understand them and make connections.

Science Learning Value
Science learning value means students are motivated to learn science because they perceive value in learning science. Students also reported significant increases in their science learning value motivation category ($p <$ 0.001). The results indicated that students perceived the value of learning chemistry. Items 16, 17, 19, 20 increased significantly after post-test

TABLE III

Comparisons of SMTSL items with selected items between pre- and post-ARCS instruction

Motivation categories	Item No.		Pre-test Mean	Pre-test SD	Post-test Mean	Post-test SD	*T*
SE	3.	I am sure that I can do well on science tests.	3.00	1.28	3.31	0.76	2.41**
	6.	During science activities, I prefer to ask other people for the answer rather than think for myself.	3.45	1.27	3.63	0.80	3.25**
	7.	When I find the science content difficult, I do not try to learn it.	3.09	1.06	3.78	0.78	2.71**
ALS	8.	When learning new science concepts, I attempt to understand them.	3.35	1.16	4.27	0.60	2.08*
	9.	When learning new science concepts, I connect them to my previous experiences.	3.94	1.03	4.10	0.50	1.99*
	10.	When I do not understand a science concept, I find relevant resources that will help me.	3.78	1.03	3.39	0.80	2.10*
	12.	During the learning processes, I attempt to make connections between the concepts that I learn.	3.94	1.05	4.06	0.54	3.00**
	15.	When new science concepts that I have learned conflict with my previous understanding, I try to understand why.	3.78	0.99	3.90	0.76	1.88*
SLV	16.	I think that learning science is important because I use it in my daily life.	3.45	1.22	3.72	1.08	1.73*
	17.	I think that learning science is important because it stimulates my thinking.	3.33	1.11	3.73	0.83	3.12**
	19.	In science, I think it is important to participate in inquiry activities.	3.96	1.18	4.33	0.59	2.93*

TABLE III

(Continued)

Motivation categories	Item No.		Pre-test Mean	Pre-test SD	Post-test Mean	Post-test SD	T
	20.	It is important to have the opportunity to satisfy one's own curiosity when learning science.	3.27	1.11	3.80	0.87	3.75***
PG	21.	I participate in science courses to get a good grade.	2.71	1.20	2.49	1.07	−1.50
	22.	I participate in science courses to perform better than other students.	2.14	0.96	2.02	0.86	−0.86
	23.	I participate in science courses so that other students think that I'm smart.	1.75	0.77	1.80	0.85	0.57
	24.	I participate in science courses so that the teacher pays attention to me.	2.02	0.91	2.15	0.97	0.84
AG	26.	I feel most fulfilled when I feel confident about the content in a science course.	4.02	1.16	4.27	0.83	1.32
	27.	During a science course, I feel most fulfilled when I am able to solve a difficult problem.	4.02	1.05	4.26	0.86	0.74
	28.	During a science course, I feel most fulfilled when the teacher accepts my ideas.	3.59	1.10	3.76	0.97	1.10
	29.	During a science course, I feel most fulfilled when other students accept my ideas.	3.49	1.07	3.76	0.79	1.88*
LES	31.	I am willing to participate in this science course because the teacher uses a variety of teaching methods.	3.45	1.06	3.98	0.68	3.43***
	35.	I am willing to participate in this science course because the students are involved in discussions.	3.24	0.91	3.86	0.78	7.94***

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

($p < 0.05$). These items mean that our ARCS instruction made students appreciate the value of chemistry: that it can be used in daily life, can stimulate their thinking, and it allows them to participate in inquiry activities. Especially after the instruction, students felt the importance of satisfying one's own curiosity was very important in learning chemistry.

Performance Goal

Performance goal refers to a student's goal in science learning as being to perform better than other students. Despite the lack of significant changes in this category, students reported a substantial change in each item. In the four items listed in Table III, for items 21, 22 there was a decrease but in items 23, 24, an increase. However for all items there was no significant change. The fact that for items 21, 22 there was a decrease means that students learnt chemistry but not for getting a high grade and having a good performance in the class. But the increase in ratings of items 23, 24 indicated that students still want other students to think that they are smart and the teachers to pay attention to them. These students are still motivated by external rewards as they want to get more attention from other people.

Achievement Goal

Achievement goal refers to students feeling fulfilled as they increase their ability during science learning. The achievement goal category has the highest average rating among the scales – students being strongly motivated by their achievements. There is no significant difference between pre and post-tests on this scale for the experimental group. In Table III, scores of items 26 and 27 are both rated above 4, which means students strongly agreed that they were more fulfilled when they could solve a difficult chemistry problem. The increase in scores for items 26, 27, 28, 29, indicates students felt more confident and more fulfilled during the acid and base instruction than previously. As item 29 has a significant change, it indicates that students put more emphasis on the acceptance of their classmates.

Learning Environment Stimulation

Learning environment stimulation refers to the classroom-learning environment, such as the curriculum content, teacher's teaching and students' interaction that increased the students' willingness to learn science. There are six items in this category. From students' answers we find the learning environment we created for ARCS instruction did not significantly change students' willingness to participate in the course. But in Table III, item 31, students think that the teacher used a variety of teaching methods and

TABLE IV

Analysis of students' achievement scores between pre- and post-test in control and experimental groups

Test	Class	N	Mean	SD	F
Pre-test	Experiment	52	68	10.06	1.01
	Control	51	64.9	10.99	
Post-test	Experiment	52	68.49	10.69	5.15***
	Control	51	59.9	10.99	

$^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

TABLE V

Using pre-test as covariant to identify the post-test difference between experimental and control group

Source	SS	df	MS	F
Post-test	1024.26	1	1024.26	16.70***
Error	6135.14	100	61.35	

$^{***}p < 0.001$.

in item 35, students were involved in discussions. These two items have significantly increased ($p < 0.001$). It means students perceive that the ARCS instruction changes teacher's teaching method and their level of involvement in the class.

Changes in Students' Achievement

ANOVA analyses were applied to analyze the difference between the experimental and control groups' achievement on test results (see Table IV). The achievement scores of the two classes were not significantly different before the instruction ($F = 1.01$), but were significantly different in the post-test ($F = 5.15$, $p < 0.001$). In addition, students' achievement scores showed a significant change ($F = 0.47$, $p < 0.001$) between the pre- and post-test in the experimental class. Furthermore, using the pre-test as a covariant, we found (see Table V) there is still a significant difference on the post-tests between the experimental and control groups ($F_{(1, 100)} = 16.70$, $p < 0.001$). These results all indicated that students who participated in the ARCS instruction could significantly improve their achievement scores on acid and base concepts.

TABLE VI

Comparisons of students' on task time

Time	Before experiment of students	During experiment of students
0 min–10 min		
10 min–19 min	2 (4.88%)	
20 min–29 min	13 (31.71%)	2 (4.88%)
30 min–39 min	16 (39.02%)	6 (14.63%)
40 min–49 min	9 (21.95%)	22 (53.66%)
50 min	1 (2.44%)	11 (26.83%)

Changes in Students' On-Task Time

Use of students' self-assessment could help us understand the students' level of engagement before and during ARCS instruction. In a 50-minute class time, most students evaluated themselves as spending between 20 to 39 minutes of real on-task time. During the experimental trial period, most students would spend more than 40 minutes on learning. More than eleven students reported they could concentrate on learning for the whole class time. This data (see Table VI), supported our previous findings that the ARCS instruction would increasestudents' willingness to participate in the class.

DISCUSSION

The purpose of this study was to apply the ARCS model in the design of an acids and bases unit to promote a class of 11th graders' learning motivation, and to investigate the difference between students' learning motivation and achievement before and after a chemistry lesson. In the design section, the ARCS model provides a guideline for analysis of the status of student motivation before instruction. It also helps researchers in designing strategies for following ARCS instruction to meet students' needs. The goal for this approach was to ensure that the teachers would identify the key motivational characteristics of the learners, in the content to be taught. This process would also help to ensure that teachers did not just design extraeneous strategies to capture student attention without regard to the characteristics of the students and the other categories in the ARCS model.

Learner' motivation interacts with the processes of learning activities in complicated ways. Designing a curriculum to promote student motivation needs an expert chemistry instructor, who can easily gauge the students' motivational level and make adjustments as appropriate (Keller, 1999; Song & Keller, 1999; Shellnut, 1999). Although the first participant in the study was an experienced chemistry teacher, who designed a lesson that helped students increase their motivation, we stress that this ARCS motivation design process is not just the domain of experts. Suzuki and Keller (1996) made an evaluation of the effectiveness of this motivational design process, and more than two-thirds of participating teachers (both experienced and less-experienced teachers) felt that it definitely helped them produce a more effective motivational design. Nonetheless, the designer in this study suggested that to analyze the motivation section is the most difficult part, and it seemed to include more than one motivational component – as consistent with Shellnut's (1999) conclusions.

We used the instrument SMTSL to assess the six dimensions of students' motivation in learning chemistry. Results indicated that the acids and bases ARCS instruction promoted the experimental classes learning motivation – in self-efficacy, active learning strategy and science learning value. It means that our instruction design can arouse students with low motivation and interest in learning chemistry, making them use active learning strategies in learning and appreciate the value of chemistry learning. Keller (1987) addressed the notion that motivation could be predicted on the basis of students' level of valueing of the task and perceived ability to achieve success in the ARCS model. The use of the ARCS model to design student valued learning activities directly related to students increasing their intrinsic motivation in chemistry learning. This is consistent with Small et al. (1996), who found that the ARCS model design could make students feel competent and self-determining.

The statistical analysis revealed that the three scales: performance goal, achievement goal, and learning environment stimulation, had changed but not significantly. In the cooperative learning environment some students' learning goals had shifted from not just wanting to perform better than other students. The chemistry teacher did not put a lot of pressure on his students before and during this study. Except in using the new teaching strategies, he did not place any additional stress on or change the other physical components in the learning environment. These results supported the efficacy of our effort in decreasing the effect of extrinsic motivation on students.

We also found that using the ARCS model to design a curriculum could improve both the motivation and achievement scores for a group of students with low motivation and a low level of expectation of achievement in chemistry learning. Although motivation to learn is not the only predictor of student achievement, it seems reasonable to confirm that the ARCS instruction stimulated student motivation more than in a traditional lecture instruction mode. In addition, student time engagement in learning had increased under ARCS instruction. This also confirms and supports our finding that ARCS instruction can promote student motivation.

The results of this study have implications for chemistry enrichment programs. Knowing how to carry out instructional design, analyzing students' motivation correctly, and teaching appropriately is important. Understanding is one thing, but doing is another. It seems that more concrete practice would prevent a distorting and limiting of the effect of instruction. More efforts are needed to continue research in this area with different students and different chemistry topics. With enough studies covering a range of gender and ethnicity, an accurate picture of the complex causal relationships between the teaching and learning of chemistry will emerge.

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