Inquire learning effects to elementary school students' nanotechnology instructions

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Contents

Abstract

Nanotechnology is an emerging science that involved in different fields. This research inquired elementary school students' learning effect by using quasi-experiment, expositive-teaching and experiential-teaching methods for nanotechnology in the microcosmic world. By utilized the pretest "Nanotechnology Situational Questionnaire (NSQ)", we have selected 110 fifth grade students with similar academic performance in nanotechnology knowledge from Northern Taiwan. This research designed 2 teaching steps. The first step had 4 class sessions, and then implemented the expositive-teaching to all the students. The main learning context was related to understand nanometer definitions, characters and fundamental concepts. The second step divided 110 students into treatment and comparison groups, each group had 3 class sessions. The treatment group implemented experiential-teaching, on the other hand, the comparison group implemented expositive-teaching by PowerPoints, animations and movies. After the experiment, the 2 groups completed posttest NSQ.

The results showed: 1. Two groups were no difference in posttest NSQ score after the first step teaching, but after the second step teaching, the treatment group had significant higher scores than comparison group. It meant that experiential-teaching method was more effective than the expositive-teaching. 2. In expositive-teaching: (a) Used actual objects, students held more complete concepts and had significant learning effect. (b) The simulated model teaching facilitates learning, but students somewhat still had vague concepts. (c) Applied a simulated model to explain another simulated model, students can hardly understood difficult concept, so they still had misconceptions. Therefore, before teaching, teacher must considering cognitive development and selecting teaching methods carefully. For extensive nanotechnology education and foster talents, educators must adopting nanotechnology into formal elementary curriculum and designing a series of complete teaching plan.

Keywords: Nanotechnology, Experiential -teaching, Expositive-teaching.

Introduction

Nanometer is a popular term in the 21 century, it is relates to our daily life (Pan, 2004), nanometer phenomenon existed in natural world for a long time, the technology can be applied in many different levels and products are continuously renovating, for example, biotech, environmental industry, electrical parts, national defense, auto and aerospace all have a great development potential. Scientists predicted the microcosmic world will have a most shocking evolution. Recently in US, Japan, Europe, Korea and even China have invested large founds in the national nanometer material developments (Lee & Tang, 2006). Taiwanese government invested "National Nanotechnology Program (NNP)" since 2002, and developed many "nanotechnology materials", but the common knowledge of nanometer technology is still in a fundamental stage. The nanotechnology phenomenon can be applied in production, development, and usage of such technology is limited (Lu & Sung, 2010).

Applying nanometer concepts in teaching plan; school is the best place to strengthen citizens to understand nanotechnology knowledge through curriculum. Therefore, we must apply a series of education plans to improve learning effects, for example, analyze teaching objectives, learners' characteristics, in order to design teaching materials, methods, practice and then evaluate final outcome (Pan, 2004).

Teaching model is essential to the effect of strategies-based instructional education (Dansereau, 1995; Fang, & Guo, 2000). The expositive-teaching is a teaching method can display a meaningful learning. Teachers organize the teaching materials and by using a systematic verbal methods to teach students. Students will combine new and prior knowledge, which further reorganize into their own cognition structure (Ausubel, 1968). In contrast, in experiential-teaching, students learn from experiencing real, simulated or dramatized situations. Through the teaching process, students are immersed in practical experiences that model real-world issues. So the Students can analyze and process their experiences, form ideas or theories about issues, ideas and/or problems, make generalizations, reflect on their learning and future applications (State schooling, 2012). Experimental activities encourage affect reasoning, critical thinking, understand of science and also help students to develop the ways of producing knowledge (Akdeniz, Cepni & Azar, 1998).

The nature phenomena of nanometer are appeared in our daily life for a long time, but it is hard to observe by eyes, also nanotechnology concepts are seldom applied in the elementary school curriculum in Taiwan. This study applied experimental design with "learning by doing" and "meaningful learning" theories. We apply sensual organs generated experience to connect with experiential-teaching theory. In contrast, we applied expositive-teaching methods in order to allow student's prior concepts to connect with new concepts, further produced transfer learning. Finally, the study inquired the learning effect between experiential-teaching and expositive-teaching, in order to facilitate nanotechnology concept course design in the future.

Background

The Nanotechnology Talent Investment Program in Taiwan

The investment for science talents directed the national competitiveness (Deway, 1938). Therefore, nanotechnology, biotechnology and computer technology are the main directions of technology development in this century. The nanotechnology development and research started by Feynman in 1959. It is recognized as one of the most important industries in the 21st century (Lee & Tang, 2006). The technology development and research brought new resource development and application to current and future world. Many advanced countries also invested large resources to this field and further listed as an important national development program (Wu, 2002).

Taiwanese government departments invested large financial resources in nanotechnology development. The first stage "National Nanotechnology Program (NNP)" started from 2002 to 2007 in Taiwan. This NNP program was designed for education and research industries, through the nanotechnology development to develop new products for using in communication, energy, medical, environmental and food industry, further improves the quality of life. (The Office of National Nanotechnology Program, 2006; Lee & Tang, 2006). In the education field, by letting students understand nanotechnology and providing sufficient talents, the education department started "Nanotechnology Talent Investment Program" in 2003, for the students in kindergarten, elementary school, high school, university to post graduate studies, workforce extended training and further expanded to lifetime training. In 2004, nanotechnology materials have already appeared in textbook in the elementary school (Chen, 2004).

Currently Taiwan is in the progress of the second stage NNP, which started in 2009 for a period of 6 years (2009 - 2014), it was intended to continue the first stage in 2002 for improving technology development and competitiveness of Taiwan (Wu, 2007)

Expositive-Teaching

Language is an important facilitator of meaningful reception and discovery learning. A language's general facilitating role in cognitive is mediating implicit verbal response in concept formation (Ausubel, 1968). Verbal generalization is particularly important for concept attainment in a learner (Heidbreder & Zimmerman, 1955). The expository teaching and reception learning are typically verbal or discovery learning, as Gagne and Smith (1962) point out, it may be either verbal or nonverbal.

According to Ausubel's meaningful learning theory, the expositive-teaching is an efficient and effective way of organizing classroom learning method. This teaching method offers the educator the most direct route for laying a foundation for higher order thinking (Ausubel, 1963). The expository approach is notion of 'reception learning', because the material to be covered is presented in a fairly complete and meaningful form (McInerney & McInerney, 2002), it primarily focuses on teaching general ideas to comprehend one specific concept, otherwise known as deductive reasoning (Woolfolk, 2004).

The expository instruction attempts to present information to learners in a form they can easily access and understand, so the expository methods include demonstrating, lecturing, explaining, narrating, requiring students to read a textbook or manual, showing students an instructional video, or asking students to work through a computer program presenting information. It is assumed that learners will process new information thoughtfully, and that it will link in an organized manner with their prior knowledge (Woolfolk, 2004). Therefore, teacher must recognize the need to subdivide, translate, and structure the information into a more digestible form for the learners, and introduce the knowledge in a logical and systematic manner (Ausubel, 1968 & 1963).

Ormrod (2000) reports that teachers can enhance students' learning from expository instruction if teachers: 1. Begin the lesson with an 'advance organizer', clarifying the objectives for the lesson and indicating how the key concepts are interrelated. 2. Present points in a clear and coherent sequence as the lesson progresses. 3. Connect new information with students' prior knowledge. 4. Use visual aids to illustrate important points and to attract attention. 5. Apply verbal and visual cues to highlight important points. 6. Pace the presentation at the optimum rate to allow students time to process information and to take notes if required. 7. Summarize key points again to end the lesson, and draw attention again to notes on the whiteboard and the lesson objectives (Woolfolk, 2004).

Experiential –Teaching

The experiential-teaching is a teaching method through hand-on experience that students learn about the world and only use their prior experiences to apply to the world. Good experiences were most valuable and useful. According to Kolb, Duru and Itin they also argued that "learning is best facilitated in an environment where there is dialectic tension and conflict between immediate, concrete experience and analytic detachment" (Kolb, 1984). "The most effective methods at the bottom of cone involved the student active participation in hands-on learning activities" (Duru, 2010). "Experiential-learning is the process of making meaning from direct experience" (Itin, 1999), it is learning through reflection on doing, which is often contrasted with rote or didactic learning. Therefore, learning is "the process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming experience" (Kolb 1984). David Kolb and Roger Fry (1975) argued that effective learning entails the possession of four skills: concrete experience abilities, reflective observation abilities, abstract conceptualization abilities and active experimentation abilities.

Kyriacou (1992) described the experimental teaching as the use of learning activities where pupils are given a marked degree of ownership and have a control over the learning activities used. As observed by Brookfield (1983) the term 'experiential-learning' is being used with two connotations. On the one hand, it is used to describe the learning where a student acquires and applies knowledge, skills and feelings in an immediate and relevant setting. It thus involves a 'direct encounter with the phenomena being studied rather than merely thinking about the encounter, or only considering the possibility of doing something about it" (Borzak, 1981). So it has identified two basic characteristics: Experiential-learning is an emphasis on learning by doing and an emphasis on pupil decision-making (Waterhouse, 1990).

Dewey (1938) and Kolb (1984) suggest concrete experience alone does not amount to experiential-learning. To transform experience into new knowledge, students need to derive meaning from that experience. They do so by reflecting upon its connection to their own current understandings. Conscious engagement with direct experience is precisely where experiential-learning and inquiry-based learning are converged. Therefore, it includes learning that comes about through reflection on everyday experiences. The experiential-learning is equivalent to personal change and growth, learning is facilitated when: 1. The student participates completely in the learning process and has control over its nature and direction, 2. It is primarily based upon direct confrontation with practical, social, personal or research problems. 3. Self-evaluation is the principal method of assessing progress or success (Deway, 1938).

Method

Experiment Design

This study used quasi-experiment to analyze students' nanotechnology learning outcome between expositive-teaching and experiential-teaching. Before the experiment, we used "Nanotechnology Situational Questionnaire (NSQ)", tested 110 fifth grade students and conducted 2 steps teaching. The first step took 4 sessions for a subtotal of 160 minutes, the teacher taught all students about nanotechnology concepts by PowerPoint, animation, and movies. The second step separated the 110 students into 2 groups of 55 students each and labeled them "comparison group" and "treatment group". The comparison group used expositive-teaching method by the PowerPoint, animation and movies, on the other hand, the treatment group used experiential-teaching by hand-on approach. After the experiment, two groups conducted the NSQ posttest. According to the pretest, posttest data and inquired the learning effect for the two different teaching methods. The results can be applied to future nanotechnology curriculum design in Taiwan (Table 1).

Table 1. Experiment Design and Teaching Content

Procedure	Teaching content & Practice
Before teaching	Conducted NSQ pretest
Teaching Step 1 (160 Min)	Teaching content（160 Min）：Expositive-teaching Nanometer definitions（40 Min)；Surface effect（40 Min)；Size effect（40 Min)；Photonic crystals（40 Min). Method： Instructor prepared the PowerPoint slides, animation, movies related to the nanotechnology conception
Teaching Step 2 (120 Min)	Teaching content（120 Min）： Lotus effect（40 Min), *Carbon-Nanocapsule*（40 Min), Inquire the atomic structure of Nanoparticles e and Nanotubes（40 Min). Method： 1.Treatment group: Experiential-teaching content and action Lotus effect: Drip some water and some dust on the lotus leaf, and then observe the interaction of water and dust. Nanoparticles : Burn the bottom part of a cup and drip a drop of water into it, while moving the water drop around the cup and observe the interaction between water and carbon deposit. Inquire the atomic structure of *Carbon-Nanocapsule* and Nanotubes: Construct C_{20}, C_{60}, C_{80} and C_{120} atomic structures. 2.Comparison group: Expositive-teaching Instructor prepared the PowerPoint slides, animation, movies of the lotus effect, *Carbon-Nanocapsule* and inquire the atomic structure of *Carbon-Nanocapsule* and Nanotubes.
After teaching	Conducted NSQ posttest

Participants

We selected 110 fifth grade students from New Taipei city in Northern Taiwan. According to pretest NSQ, students were assigned to treatment and comparison groups (55 students each). The t-test of the NSQ pretest score (t=.169, -.305, 1.057; p=.682,.761,.293) revealed no significant differences between the 2 groups. The result showed two groups were similar in academic performance (Table 2).

Table 2. Analysis Two Groups in the NSQ Pretest Scores

Instrument	Group	n	Mean	SD	t value	p value
Total	Comparison	55	12.16	3.190	.169	.682
	Treatment	55	11.87	4.164		
Teaching step 1	Comparison	55	6.18	1.877	-.305	.761
	Treatment	55	6.31	2.456		
Teaching step 2	Comparison	55	5.98	1.995	1.057	.293
	Treatment	55	5.56	2.150		

*p＜.05 **p＜.01

Research Instrument

The NSQ was created according to expert concept map, declarative knowledge statement in elementary school nanotechnology curriculum. And NSQ was designed to assess student's comprehension-ability in nanotechnology concepts that contained 12 situations, 25 questions by 4 multiple-choices.

After NSQ first draft was created, we have selected 6 elementary middle-grade students to read the NSQ first draft and modified the unclear questions and choices. Then we invited two science professors and five experienced primary school teachers to comment on the content validity of the questions. Finally, the pretest of the NSQ draft was conducted with 232 sixth grade elementary school students, who had finished learning content. The internal consistency of the NSQ was .80, the question difficulties were between .32 and .77, and the discrimination indicated between .38 and .71 (Table 3).

Table 3. Situation and Questions of NSQ

Content	NSQ		Content	NSQ	
	Situation	Number of questions		Situation	Number of questions
Nanometer definitions	1	3	Lotus effect	8	3
Surface effect	2	3		4	1
	10	1	Nanoparticles *Carbon-Nanocapsule*	7	2
Size effect	3	2		11	2
	5	1	Nanotubes	9	1
Photonic crystals	6	2		12	2
	9	2	TOTAL		25

Data Gathering and Analysis

We collected student data from pretest and posttest NSQ. By using SPSS17.0, we analyzed the learning effect of comparison and treatment groups.

Results

Children's Learning Effect in Nanotechnology

Table 4. Analysis Two Groups in NSQ Pretest and Posttest Scores

Group	step	Posttest (N=110)		Posttest (N=110)		t value	p value
		M	SD	M	SD		
Comparison	Total	12.16	3.190	15.13	4.078	4.557	.000**
	step 1	6.18	1.877	7.89	2.485	4.336	.000**
	step 2	5.98	1.995	7.24	2.099	3.515	.000**
Treatment	Total	11.87	4.164	18.53	2.624	8.842	.000**
	step 1	6.31	2.456	8.47	2.133	5.863	.000**
	step 2	5.56	2.150	10.06	1.068	10.887	.000**

*p<.05 **p<.01

Although Nanotechnology knowledge is not formally applied into elementary school curriculum, students are also unfamiliar to this field. This study found students were more interested in learning. Data showed in Table 4, demonstrated both groups in NSQ pretest and posttest scores (t=4.557, 8.842; p=.000**) displayed significant progress after teaching (Table 4).

From this t-test result showed two groups had learning effect after teaching. In order to understand the learning effects of two different teaching methods, we used ANOVA compared the performance of two posttest in 2 teaching steps (Table 5).

Table 5. ANOVA Analysis Two Groups in 2 Steps NSQ Posttest Scores

Test	Group	n	Mean	SD	SS	SW	F	p value
Posttest	Comparison	55	15.13	4.078	317.900	1269.818	27.038	.000**
	Treatment	55	18.53	2.624				
step 1	Comparison	55	7.89	2.485	38.409	359.055	6.164	.059
	Treatment	55	8.17	2.133				
step 2	Comparison	55	7.24	2.099	135.309	299.564	48.782	.000**
	Treatment	55	10.36	1.068				

*p<.05 **p<.01

ANOVA result showed two groups had significant difference after experiment (F=27.038, p=.000). The first teaching step revealed no significant differences between the comparison group and treatment group (F=7.164, p=.059), but in second teaching step, the score was significant different after nanotechnology teaching (F=48.782, p=.000). In order to understand the learning effects of two different teaching methods, we compared the concept performance of two groups between "the first step teaching" and "the second step teaching" (Table 6).

Table 6. Learning Concepts of Two Groups' NSQ Posttest Scores

NSQ & Content		Comparison		Treatment		t value	p value
		M	SD	M	SD		
Teaching content (Step 1)	Nanometer definitions	2.15	.756	2.28	.655	-1.887	.062
	Surface effect	1.91	.888	2.12	.942	-1.875	.063
	Size effect	1.16	.877	1.35	.712	-1.671	.098
	Photonic crystals	2.67	1.415	2.72	1.027	-1.465	.146
Teaching content (Step 2)	Lotus effect	3.11	1.012	3.85	.440	-4.276	.000**
	Nanoparticles *Carbon-Nanocapsule*	2.58	1.083	3.73	.604	-5.653	.000**
	Nanotubes	1.55	.741	2.48	.641	-4.818	.000**

*p<.05 **p<.01

From table 6, in the first step teaching, the data displayed no differences in learning concepts (*Nanometer definitions, Surface effect, Size effect and Photonic crystals*) between the treatment group and comparison group. The results indicated that the same teacher applied the same teaching methods to the 2 different groups and the outcomes were the same, it meant the comparison group had no differences.

From the second step teaching, it displayed significant differences in learning concepts (*Lotus effect, Nanoparticles, Carbon Nanocapsule and Nanotubes*) between the treatment group and comparison group. This meant the teacher applied different teaching methods to the treatment group, and it had a significant learning effect (t=-4.276, -5.653, -4.818, p=.000). In another word, applied experiential-teaching method was more effective than expositive-teaching method.

Analysis Student Nanotechnology Concept in Different Teaching Methods

We analyzed 2 groups of student concept in "the second step teaching" about *Lotus effect, Nanoparticles, Carbon-Nanocapsule and Nanotubes* (Figure 1).

Figure1. Comparison of Two Groups in Nanotechnology Concept Learning

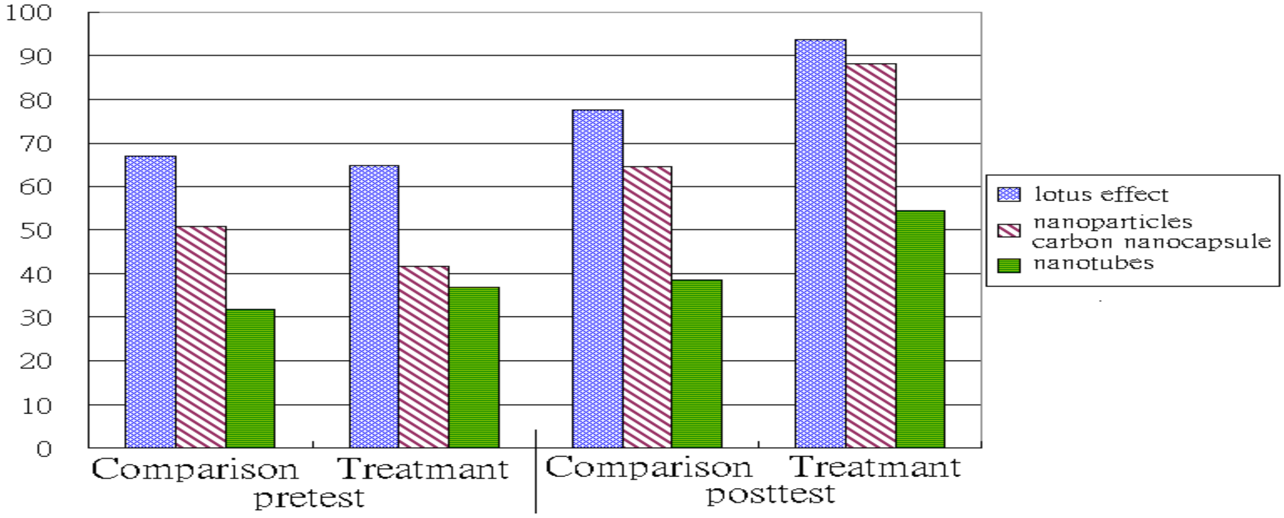

Figure 1 showed, the 2 groups had correct answer in *lotus effect* of 65%+ in NSQ pretest. All students had already learned the appearance of the *lotus* in the 4th grade science curriculum. The expositive-teaching method in posttest comparison group, the students had correct answer from 66.82% to 77.73%, improved 10.91% in *lotus effect.* The experiential-teaching method in posttest treatment group, the students had correct answer from 65.00% to 93.64%, improved 28.64% in *lotus effect.* After teaching, these data displayed treatment group was 15.91% higher than comparison group within the posttests.

Regarding on the concepts of *Nanoparticles* and *Carbon-Nanocapsul*e: in the pretest, comparison group about 51.91% students had prior knowledge. On the other hand, the pretest treatment group 41.82% had the prior knowledge. After experiment, the comparison group and treatment group improved 13.64% and 46.36% respectively, the improvement percentage in treatment group was higher than comparison group by 23.63%; this meant by using "experiential-teaching" could intrigue students' interest, students had clearer concepts and further facilitated learning. The students' concepts of *Nanoparticle* and *Carbon-Nanocapsule* for the "experiential-teaching" (treatment group) were more effective than "expositive-teaching" (comparison group).

The concept of *Nanotubes* was less concrete than *Lotus effects, Nanoparticles* and *Carbon-Nanocapsule*： However, the expositive-teaching (comparison group) only improved 6.82% between pretest and posttest (from 31.82% to 38.64%); in contrast the experiential-teaching (treatment group) improved 17.73% between pretest and posttest (from 36.82% to 54.55%). This explains students had physical experience and can understood abstract concepts better by experiential-teaching methods.

From these results, treatment group had lower scores than comparison group in three nanotechnology concepts before the second teaching step, but the treatment group improved scores after the second teaching step, so it was more efficient. Therefore, applying experiential-teaching in nanotechnology concepts' learning was an appropriate teaching method.

In experiential-teaching, we used different hand-on experience in classroom and it had different effects. Students learned concept of *lotus effect* by operated and compared the water drop in different conditions between "water slides" or "water rolls" on different surfaces. Through operated actual objects by themselves, students attained complete concepts and then constructed knowledge, so they had significant learning effect. In learning of *Nanoparticles* and *Carbon-Nanocapsule*, teacher took out a *buckminsterfullerene* (C_{60}), explained the simulated *Carbon-Nanocapsule* (C_{60}) model to students, students clearly understood the relations between *Nanoparticles* and *Carbon-Nanocapsule* through made up a *buckminsterfullerene* (C_{60}) model, but they were difficult to imagine the magnification world of *Carbon-Nanocapsule* (C_{60}) and had vague concepts. In teaching concept of *Nanotubes*, teacher applied basic *Carbon Nanocapsule* (C_{60}) model, asked students to make up C_{20}, C_{80} and C_{120}, further illustrated the characteristics and development of *Nanotubes*, but students still felt it is abstract and were unable to imagine the pattern of *Nanotubes*, so they had misconceptions.

Conclusion and Recommendations

Conclusion

Nanometer is microcosmic world, it is difficult to observe and understand for elementary students. In this research, while teacher applied expositive-teaching, students where having difficulties in understanding the abstract form, on the other hand, when the same teacher applied experiential-teaching, it offered a tangible model and provided a hand-on experience, through this way, students can construct a more concrete knowledge, further able to apply the concept to their daily life.

In experiential-teaching, different hand-on materials offered various kinds of experience to become different results. From concept of *lotus effect,* students' leaning experience through observed directly and compared different conditions between "water slides" or "water rolls" on different surfaces, understood the *lotus effect* of *superhydrophobicity* and *self-cleaning*, further recognized many nanotechnology products on the market that have applied *lotus effect*. By actual objects, students could operate and observe themselves, and so they held more complete concepts and can explained to anthers about this phenomenon.

Analyze students' learning process in concepts of *Nanoparticles* and *Carbon-Nanocapsule*. The students were unfamiliar with *Carbon-Nanocapsule* *(*C_{60}*)* and could not understand it is constructed by 60 *nanoparticles* in the form of pentagons & hexagons. The teacher guided students through constructed *buckminsterfullerene (*C_{60}*)*, further illustrated clearly the relations between *Nanoparticles* and *Carbon-Nanocapsule.* Established a simulated model allowed students facilitate learning, students also realized the structure of *Carbon-Nanocapsule,* but they were having difficulties in merging the *Carbon-Nanocapsule* and the physical object together, therefore, they somewhat had a vague concept.

In concept of *Nanotubes*, teacher applied basic C_{60} atomic structure, asked students to fabricate C_{20}, C_{80} and C_{120} atomic structure according to the characteristics of *buckminsterfullerene* (C_{60}), further described pattern and property of *Nanotubes*, and how it can applied to future life. By applying a simulated model to explain another simulated model, although students understood an advantages of using *Nanotubes*. Nevertheless, students needed imagination to construct a concept, so they were difficult to understand the arrangement of *Nanotubes* and how it can be constructed as an object. Consequently, students had misconceptions.

Student's cognitive development in elementary school belonged to "concrete operational stage" or "formal operational stage" (By Piaget's cognitive-developmental theory), because nanometer is microcosmic and it is unable to observe by sense organs, so students were difficult to understand it. In this research, teacher used experiential-teaching, this offered experiential learning opportunities and also improved learning effect for students.

In experiential-teaching, different hand-on materials had different learning influences. The actual objects teaching method (e.g. concept of *lotus effect),* students held more complete concepts through hands-on operation and observed directly. In simulated model teaching (e.g. concept of *Nanoparticles* and *Carbon-Nanocapsule*), it facilitated study and assisted students in understanding object's structure, but students somewhat had vague concepts. Applied a simulated model to explain another simulated model (e.g. concept of *Nanotubes*), students were difficult to imagine object's structure and held some misconceptions. Therefore, before teachers conduct teaching, they should consider students' cognitive development and select a suitable teaching method.

Recommendations

Science education have deep influence to the country and society, because nanotechnology is closely related to our daily lives, so Taiwanese government had been invested large number in human and financial resources on nanotechnology field. For improving nanotechnology industry, and allowing students to learn about nanotechnology and the application of the technology, it became a major issue in Taiwan.

The Taiwanese elementary school science education objective is: By using science curriculum and teaching design to activate students' motivation, interest and allowing students to use the science concept in their future daily lives. Therefore, a complete teaching method needs to have a better curriculum design, by combining students' experience and suitable teaching activities; this can further communicate science concept, and allowing students to apply into their daily lives. Nanotechnology is a cross-field emerging science, nanometer is a microscopic, amazing, hard to imagine world, although nanometer phenomenon appears in our daily lives. In Taiwan, the elementary school curriculum hardly apply nanotechnology in the official curriculum at present.

In order to allow students have more complete concept of nanotechnology, nanotechnology cognition and literacy. Educators must aware the importance of combining education with nanotechnology. For applying the nanotechnology to the whole nation's education, we must apply carefully through a complete course design and activities. If the complete course and activities can activate students' interest, then it can achieve the nanotechnology concept learning goal.

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