A science teacher's beliefs and practices of teaching nanoscience in an informal setting

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Abstract

Nanoscience is a branch of science and technology that is new and interdisciplinary, thus integrating it in curriculum presents many challenges to science teachers. This research aims to investigate how a middle-school teacher's beliefs and practices support student learning in an informal setting, a nanoscience camp. The corpus of data included video-recorded classroom observations and teacher interview. Three major findings emerged. *First*, in designing the curriculum, the teacher followed the sequence of understanding, experiencing, and applying. He indicated the importance of infusing examples that are relevant to the everyday lives of the students to spark their interests in the subject. Hands-on activities were designed for students to experience the properties of nanoscale materials and different applications of nanoscience were raised to expand students' understanding. *Second*, a "learner-centered" instruction was observed in accordance with the teacher's belief that the curriculum development should consider students' prior knowledge and interests. *Third*, the teacher used the practices of simplifying, guiding, practicing, and inspiring in teaching nanoscience concepts. In particular, simple analogies were used to facilitate student understanding. The results gathered from an informal setting provided implications for formal curriculum development, teacher education, and professional development in integrating nanoscience into science classrooms.

Key word：nanoscience, nanoscale, teacher beliefs, teaching practices

I. Background

Nanoscience is a branch science and technology that is new and interdisciplinary. Nanoscience has been applied to advance product development, technology and information in health care, agriculture products, and energy sustainability. In order to have students and adults understand the nature and significance of Nanoscale Science and Engineering (NSE), they must have science literacy. Thus, how to integrate the "Big Ideas of Nanoscale Science & Engineering" (Stevens, Sutherland & Krajcik, 2009) into the current science education curriculum has become a urgent and important question for science teachers. Since NSE involves interdisciplinary knowledge, teachers need to learn the core concepts of NSE across different content areas and acquire new teaching strategies. This research aims to explore the difficulties of an experienced science teacher's experienced during the unit of "Butterfly Photonic Effect" in n nanoscience camp, as well as the teaching strategies they utilized, and the application of teaching strategies in solving those problems to make the subject interesting and easy to understand to students.

II. Research purposes and problems

The purpose of the study was to have an in-depth observation of a teacher when he taught nanoscience in an informal setting to examine how his teaching beliefs and strategies relate to how nanoscience curriculum is designed and implemented.

1. What was the core concept and brief of the teacher when he or she designed the nanoscience curriculum?
2. What strategies did the teacher use to resolve the problems he encountered in implementing the curriculum?

III. Literature Review

A. The importance of NSE

In human history, there were already three industrial revolutions in human history already happened. With the invention of steam engine in the 18th century, it started the industrial revolution lasted over a century, as known as was the first Industrial Revolution. The second revolution initiated the electrification. In the third Industrial Revolution, computers changed the lives of human beings. Now, the nanoscience will soon lead us to the fourth Industrial Revolution.

The rapid growth of nanoscience in recent years can be observed via environmental protection, medical treatments, informational conservation and application of delivering any nanoscience-related products to the daily lives. In recent times, scientists from all over the world considered nanoscience will bring human kinds to the fourth Industrial Revolution. As many countries valued the importance of this newly raised nanoscience, along with possible substantial industrial profits it carried, they invested considerable budgets in research and nanoscience development. Thus, nanoscience had already become a technological competition between countries. As education was the foundation of technology and academic research, as well as both represented a concrete attribution on the power of a nation, a high quality of technology and academia was then become the best competition tool of a nation when undergoing knowledge economy and globalization.

A pyramid structure can be used to analyze the technology research of a country; the more profound the foundation was, the higher it became. As one of the important members of Asia-Pacific economy, the industry of our nation had rapidly transformed from a follower to an innovator, as well as a leader. With this phenomenon, nanoscience education will need to revise overall goals in future industries, industrial demands of human resources, and application of nanoscience to daily life, considered the origin of a knowledge supply chain. It was necessary to train general public with the appreciation of nanoscience to face the new nanotechnology world in the future (Li, Lin, Wu, Hung & Tsai, 2003).

B. The development, promotion, and teaching difficulties of K-12 nanoscience education

In order to make K-12 students to be ready for the "nanotechnology society" in the future, it was necessary to develop students' nanoscience literacy. To provide students hands-on learning environment of nanoscience, develop their curiosity and interest in nanoscience, it was our purpose to develop individuals' skill to explore the process of nanoscience development and its impact on human beings. This would improve the quality of our technology education, train our citizens with nanoscience literacy, and make them understand and support government policies on science and technology research in order to prepare the future nanoscience professionals. In 2003, the Ministry of Education in Taiwan planned and executed a six-year project (2003-2008) ,"The frist section of Nanotechnology Human Resource Development Program"（Ministry of Education, 2002). By hosting regional promotion of public nanoscience, teaching seminars, promoting teaching methods for seeded teacher and all kinds of competitions, it had trained lots of seeded teachers and developed a diverse teaching materials and tools nanoscience education needs. It included supplement teaching materials, public nanoscience textbooks, multimedia teaching materials and tools for K-12, which became an important outcome on promoting nanoscience technological education in recent years. Those teaching materials were further valued by other countries *(R.P.H. Chang, 2006)*. In developing K-12 curricula on nanoscience, a convention for K-12 seeded teachers and college nanoscience professors in Taiwan integrated the teaching materials from participants' with three sets of common nanoscience education teaching materials. Each set fit different stages in high school, junior high, and elementary school that hoped to broadly promote to every K-12 school in Taiwan in the future.

However, there were many problems to teach students this new nanoscience technology. The main reason was the learning concept of nanoscience knowledge had the characteristics of cross-discipline, which across many disciplines and knowledge in different grads. This may included in subjects such as Science and Technology Comprehensive for elementary and junior high schools; Physics, Chemistry, Biology and Technology Comprehensive for high schools. When this characteristic presented on nanoscience education, there were some important topics that needed to be solved. In addition, the knowledge generated by nanoscience was a dynamic process which continued to generate new knowledge. As this was a new raising area, unlike those general disciplines, such as physics, which already clearly required college students major in physics to obtain the knowledge and skills on the four mechanics. Hence, most education training for nanoscience teachers started from traditional college departments to teach related nanoscience curricula still need a better systematic mechanic to design the curricula from a nanoscience perspective. Currently, our nation needed a clear outline for core concepts and learning indicators on nanoscience for K-12 student, as well as for the knowledge on nanoscience, the methodology for teaching, and the interest level for students on nanoscience knowledge.

Moreover, both instructors and students experienced different problems with the characteristics described above in nanoscience teaching. To instructors, they confronted the following problems: (1) How to teach nanoscience when instructors were not familiar with nanoscience? Most of them had heard about the term related to nano but not clear with the definition of nanoscience (Chen, 2005); (2) was there no enough opportunities for the professional development of instructors? There was no proper channels that provide instructors enough knowledge of nanoscience (Chen, 2005); (3) The supplemental teaching tools of nanosicence for K-12 that was already developed were theme-based curricula. The duration of these activities for this type of curricula were long. Thus it was difficult to integrate current curricula to teaching; (4) How to convert the knowledge of inter-discipline of nanoscience to teaching content? The foundation should be based on the knowledge students' already had and converted the knowledge of nanoscience into contents that were easy to understand and learn; (5) What type of contents should we teach students? What should students learn? (6) Who can help instructors when they need assistant during teaching nanoscience curricula?

C. The importance and assistance of Informal education on nanoscience to K-12 students.

The aims of teaching were to have learners understand or gain knowledge. Thus learners may be learning anytime and anywhere. Colardyn, D., & Bjornavold, J. (2004) distinguished characters of learning with formal education, non-formal education, and informal education based on the characters of teaching (see the table 1 below). The main characteristics of informal curricula was learners were the initiators and free to choose the internal motivation, which included the following four characteristics: (1) the curricula was free to participate and volunteered; (2) it was an open construction which provided learners to choose with less teaching; (3) it provided no assessment and no competitions; (4) it was group interactive and is mixed ages (Colardyn, D., & Bjornavold, J. ,2004).

Table 1. distinguished characters of learning

Formal	Non-formal	Informal
Often at the school	Institutions off-campus	Anywhere
Can be controlled	Often supportive	Supportive
Constructive	Constructive	Non-constructive
Often pre-arranged	Often pre-arranged	Occurred at a sudden
External motivation	Can be external motivation, but mostly internalized	Internal motivation
Enforced	Often volunteered	Volunteered
Teacher-centered	Assisted guided or teacher-centered	Often learner-centered
Evaluated	Often not evaluated	Not evaluated
In ordered	Mostly not in ordered	Not in ordered

Colardyn, D., & Bjornavold, J. (2004)

Falk, Dierking, and Storksdieck (2005) indicated the difference of informal science curricula from school's formal science curricula was participants free of choices other than learning from textbooks, as well as discovered and studied real sciences. Nasir, Rosebery, Warren and Lee (2006) illustrated participants often had opportunities to choose during informal science learning curricula; what to learn, when to learn, and how to learn. Moreover, the environment was safe and students were allowed to discover. Students did not need to care about their academic performance.Regarding the impact of learning on informal curricula, a study showed that it had a significant influence on the experiences students obtained during informal education can develop their interest in science at schools and further establish students' interests in future scientific research. Hooper-Greenhill (2007) identified the informal learning outcome was diverse. There are many so-called “soft” outcomes that were about attitudes, values, affections, and beliefs. Falk and Storksdieck (2005) indicated informal science curricula learning can often raise students’ interest. Renninger (2007) discovered that informal science learning curricula can provide hands-on activities for students with interest in science. It is more important to increase these students’ interest than to encourage, construct, or connect with the knowledge students’ already had. For instance, applications of hands-on situations assist students to discover problems, designs, and sophisticate experiments. Hence, informal science learning curricula can provide students with interest in different levels a more adaptive way to learn and to find the answers formal curricula can’t solve at schools.

The rapid growth of nanoscience in recent years, it is necessary to develop students’ nanoscience literacy. To provide students a hands-on learning environment of nanoscience, develop their curiosity and interest in nanoscience, it is our purpose to develop individuals’ skill to explore the process of nanoscience development and its impact on human beings. This will improve the quality of our technology education, train our citizens with nanoscience literacy, and make them understand and support government policies on science and technology research in order to prepare for the future nanoscience professionals.

However, there are many difficulties to teach students this new nanoscience technology. The main reason, compare to current academic curricula’ knowledge, is the learning concept include the science curricula in every subjects and different grades. The independence of each discipline made it impossible to teach nanoscience in any subjects. In addition, the knowledge generated by nanoscience is a dynamic process which continues to create new knowledge. Yet, our nation did not have a clear outline on core concepts and learning indicators of nanoscience for K-12 students, as well as to a combination of the curricula that appropriately developed and the current science curricula, the knowledge on nanoscience of instructors, the methodology of teaching, and the interest level of students on nanoscience knowledge.

Thus, this study planned to use informal nanoscience education activities to conduct nanoscience teaching. The feasibility of this implementation method focused on nanoscience camps for K-12 students hosted in an informal setting. Its purpose was to increase the knowledge and skills of nanoscience on K-12 students and to develop their learning interests in nanoscience, as well as to solve some issues nanoscience currently experiencing by providing strategies such as lectures, interactive teaching and hands on teaching. In addition to provide instructors references on the application of nanoscience teaching strategies.

IV. Study Design

The interpretive research method applied in this study took an in-depth analysis on the problems senior nano seeded teachers' experienced during the lesson of "Butterfly Phtonic Effect" and the strategies they used to solve those problems to help students to learn. During the first research year, the researcher went to nanoscience camps for senior teachers, observed a teaching lesson of case teacher. The researcher recorded the lesson and discovered during the primary analysis, senior seeded teachers found case teachers often teach by using plentiful teaching strategies, classes were intense and logical and teaching was friendly and attractive. The class was cheerful and students showed high learning interests which students were easy to learn the knowledge concept related to nanoscience. After initial outcome of literature review and formed the research question, the study then examined the teaching strategies teachers applied to compensate the problems they experienced during teaching. Next, the study used the initial study question to lead the observation, and started to attend nanoscience camps to collect related data on the teaching strategies case teachers applied to overcome their problems. Through the cycle of data collection – data analysis – questions definition, this study slowly formed a study theme of a situation networks for case teachers to adopt as teaching strategies, as well as the teaching difficulties and practice teaching. During the final stage of research is to compose a study report.

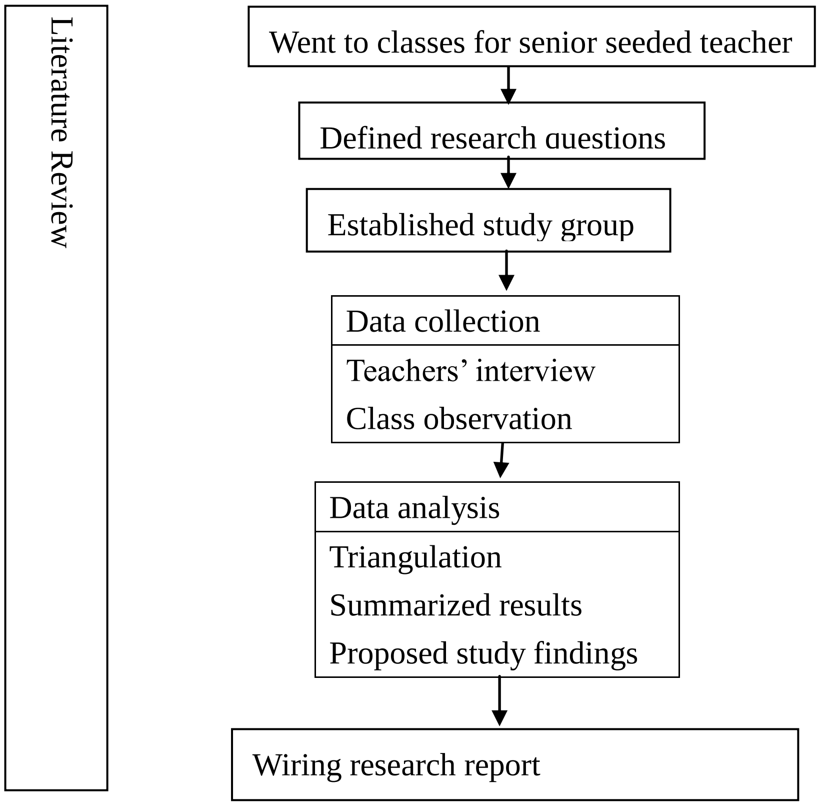


Fig. 1. Research flow chart

V. Results

A. Nanoscience camp curricula is profound and extensive, so the case teachers presented the curricula concept with an organized logical structure.

Case teachers considered camp curricula extra curricula and hope students can expose to different things. Thus, the range of curricula would prefer to illustrate differently than schools curricula. As a result, the assigned issues were most likely integrated curricula or some new technology that students were never exposed to. Therefore, the curricula from nanoscience cam is more profound and extensive.

Case teacher interview.
[Honestly, the camp curricula were more outstanding. But it is actually not that simple; it is more extensive and profound.]
[It is impossible to teach so many things if it was at a school setting]

Case teachers made the connection of teaching content more logical. During the process of lectures, not only does it is necessary to collect data, it is more important to made the content of curricula become more logical and hoped to increase the understandability of students' curricula. Case teachers used structures to affect direction of light travels, which made the change of colors in lights. It was like a special nano structure from the butterflies so there were differences in color changing from the butterfly effect. With this concept introduced, teachers can further talked about the photonic crystal concept to students.

Case teacher interview.
[Of course I tried to let it sounds more logical when I taught the process of screening]

Case teachers first used some life examples, such as Papillion butterflies, bubbles, CDs, to have students observe the changes in colors. They used the gravity caused the thickness on the tip of the bubble as an example that affect colors, and continued with structures like Polaroid, rainbow to introduce the influence of colors in structures. Later on, they explained the different structure of Papillion butterflies result in butterfly effect and lastly to talked about possible applications of Photonic crystal.

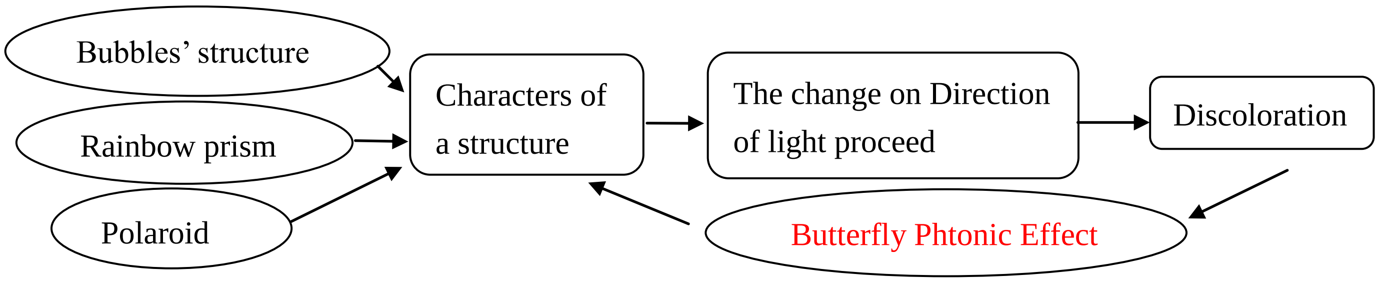


Fig. 2. Teachers' teaching structure in Butterfly Phtonic Effect.

B. Nano structure were extremely tiny to be actually observed, so the case teacher used materialization to make students observe and experience.

Case teachers considered nanoscience curricula were only limited to picture presentations. It would be better to observed with electron microscopes.

P1: Case teacher interview.txt
If we're talking about nano, the observation is still based on what the eyes can see, we didn't really let them to do some internal things ….

Case teachers explained the course using experiments, pictures, and videos. To present some abstract concepts in a specific ways to explain the imaginable phenomenon that was unable to observe from nano.

Case teachers considered nano curricula involved micro-observation which has the difficulties to observe concretely. It is a pity if Papillion butterfly effect can only be shown on pictures without actually observing with instruments. Thus the pictures of Papillion butterfly presented by case teachers during class, and use microscope to magnify its picture from a small multiple to a larger multiple. This method makes the butterfly effect to change from dazzling colors and return to its original monotone color, which was closed to observing through microscope on their own.

P 1: Case teacher interview.txt – 1:47
Okay. But if we're talking about the butterfly's ….its wings, they kept magnifying the class content, then you can use pictures to explain the phenomenon of light filter on Polaroid.
Teacher: Aha, there's not only one kind of density wave. …what makes it vibrate? It's not a string. It doesn't have s rope there. It's the electric field, magnetic field. It is the vibration between electricity and magnet. In other words, you try to imagine there were lots and lots of gaps in Polaroid sheets. …they are everywhere, aren't they? But if you took this sheet out, what's going to happen?
Students: Disappear.

C. Nanoscience is a new technology and the knowledge is interdisciplined, so the case teacher considered the prior knowledge students have when preparing the curricula. The teacher systematically designe and present the curricula, following the sequence of understanding, experiencing, and applying.

Case teachers considered nanoscience a new technology with its interdisciplined knowledge. Thus, when teaching this curriculum, it is necessary to conformed students' cognitive skills and prior knowledge or to prepare students with prior knowledge.

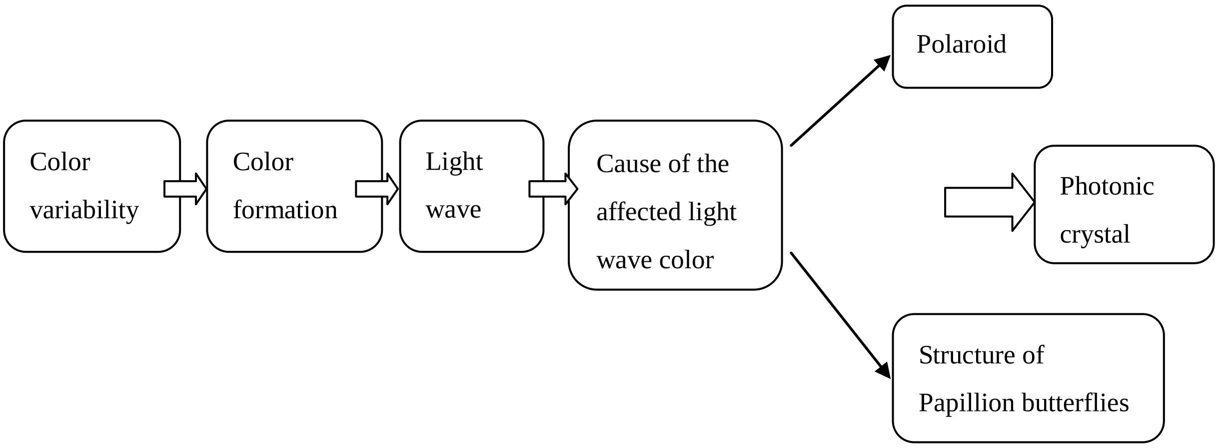
Case teacher interview

Students need to have prior knowledge on principles of optics before learning Papillion butterfly effect. In addition, it needs to combine theories of light reflection, refraction, interference, diffraction, which is difficult to teach.

a. Systematically present the curricula

The teaching beliefs of case teachers were not to make students thought nanoscience was too far from us since it is a new technology topic. The curricula should start from life examples and prior knowledge to have students understand what nano is. Then, by hands-on activities to experience the size of nano which forms many new materials makes the curricula less boring, more interested and wants to learn more. Students can also further apply nanoscience.

Case teacher interview. [When I design the activities for this curricula, we tried to put more hands-on activities so it is less boring. At least they'd think it's fun and want to learn more.]



b. Connects life examples and prior knowledge for students to know about nano

Case teachers hoped students to notice the variability of colors. Thus, in the beginning of the curricula, he told students they can observe butterflies with different colors from different angles. At the meantime, teachers led students to recall under different situations can also observe objects with different colors from different angles. He also suggested not all butterflies had this characteristic.

Curricula content 1.txt – 3:142

Teacher: This is a butterfly. ...you used to see this butterfly flying or stopped somewhere. When they vibrate their wings, their color seems to change

Curricula content 1.txt – 3:143

Teacher: Peacock. Peacock's feathers do the same thing… others like shells, fish scale, and minerals. Oh, and the Australia's gemstone, opal. Okay, here's the butterflies everyone knows. And this is its close-up shot.

Curricula content 1.txt – 3:174

Teacher: You thought when they vibrate their wings, the color changed. But it's not necessary. Not all butterflies can do this. You'll have to see their…if the scale inside the butterflies have the tiny nano-structure.

Case teachers used the prior knowledge of three primary colors and light reflection they learned in junior high to describe the color formation. Teachers also introduced wavelength frequency decides colors, three primary colors, the relationship between visions and shade, and the relationship between the color of an object and shade reflection.

P 2: M2U00300.txt - 2:25 Wavelength frequency decide colors

Teacher: What makes colors look different? What is their essence? Yes, the wavelengths are different. Yes, electromagnetic wave has all kinds of wavelength too. Let me show you the wave pattern of the electromagnet wave.

P 2: M2U00300.txt - 2:27 The light shade is formed by three primary colors

Teacher: Actually no necessary. All we need is three colors. Let's see... the projector. It doesn't have red, orange, yellow, green, blue, indigo, and violet. All it needs is these three colors.

c. Hands-on activities to experience the various in nanoscale form many new materials.

Case teacher used spring wave to introduce the basic characters of light wave and analogue the light wave with spring wave to interpret the phenomenon of light wave also has wave.

P 2: M2U00300.txt - 2:14 Basic characters of light

Teacher: Is light a particle or a fluctuation? Is it a particle or this one (operating spring wave)

P 2: M2U00300.txt - 2:15 Particle of light

Teacher: Lights, with particles like red, orange, yellow, green, blue, indigo, and violet. When every particle come out, you ate some of them, or you threw some of them away.

Light wave reflects various lights due to the different structures of objects and the pigments of its own. Under the influence of color by operating Polaroid, the color made changes, analog to color changes with partial light blocks.

◎Polaroid: Impact of light movements with grating

P 2: M2U00300.txt - 2:29 Application of Polaroid

Teacher: Part of it was blocked. Only what can pass through? It can only pass by following the direction of the gap. Do you understand? Yes? What if you have two sheets? What would happen if you have two sheets? What can you do with two of them?

P 2: M2U00300.txt - 2:31 Principle of Polaroid

Teacher: They can pass it with the same polarization direction. If not, they can't. Part of it can go through with some angles. .... 3D movies used this principle.

◎Difference of object structures affect the various in reflective light

P 1: M2U00301[3].txt - 1:6 Structures affect colors

Teacher: ...because the tap was layer by layer. Oh yeah, the nano structure inside the sea mouse is like this. Let's take a look. You can see different colors from different angles.

d. Application of nanoscience

Case teachers described the characteristics and future application of photonic crystal, as well as the applications on how technology produced similar structures after in the nanoscale of objects.

P 1: M2U00301[3].txt - 1:9 Photonic crystal and its application

Teacher: Let it transmitted following that direction so you can control the color of lights, the direction light transport. ... if we talked about cell phone, the electromagnetic wave from the cell phone should transmit here, thus there's photonic crystal in your cell phone. Yup, light would turn into light wave and be locked inside. So it doesn't hurt your brain.

C. the teacher used the practices of simplifying, guiding, practicing, and inspiring in teaching nanoscience concepts. In particular, simple analogies were used to facilitate student understanding.

The concepts of case teachers using analog of structure discoloring should first guided students to observe some discolored objects. Since the angles from observation were different, it created the phenomenon of color changes. Lastly, they used the activity of Polaroid production to let students experience how structure changes results phenomenon similar to Papillion butterfly effect.

P 1: Case teacher interview.txt – 1:107

Teacher: When we work on analog, it has the…. . It was the analog that resulted a myth. In fact, it wasn't necessary to be to over with …. But I think it was actually okay to ignore sometimes. Because they are still young, it's fun to let them know this kind of stuff at this age. We can try to develop some interest related to this matter. I think it is not a bad idea.

D. Case teachers execute the strategies to increase students' interest in learning

Case teachers planned to increase students' interest on camp activity curricula so they can get some ideas on nano phenomenon and further develop their interest related to nano issues. Thus, seeded teachers applied lots of strategies to increase students' learning interest from the learning strategies application described previously.

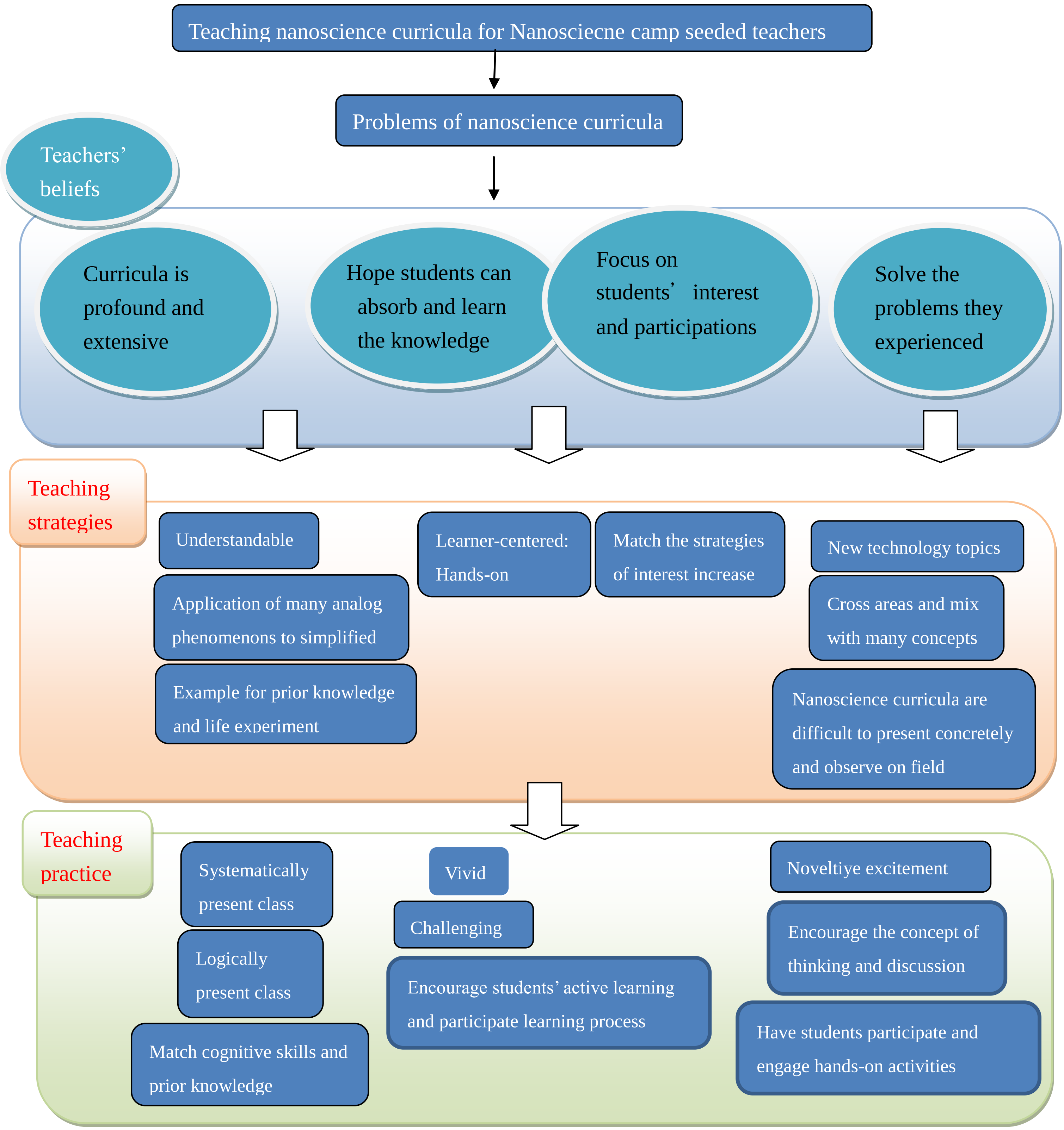


Fig. 3. The integrated results of the teaching and strategy application of Papillion butterfly effect of a Nanoscience technology camp scenario case teachers

VI. Conclusion

The results of these studies of the senior seeded teachers in the non-formal nanoscience teaching camp curricula teaching showed the following features:

First, in designing the curriculum, the teacher followed the sequence of understanding, experiencing, and applying. He indicated the importance of infusing examples that are relevant to the everyday lives of the students to spark their interests in the subject. Hands-on activities were designed for students to experience the properties of nanoscale materials and different applications of nanoscience were raised to expand students' understanding. *Second*, a "learner-centered" instruction was observed in accordance with the teacher's belief that the curriculum development should consider students' prior knowledge and interests. *Third*, the teacher used the practices of simplifying, guiding, practicing, and inspiring in teaching nanoscience concepts. In particular, simple analogies were used to facilitate student understanding. The results gathered from an informal setting provided implications for formal curriculum development, teacher education, and professional development in integrating nanoscience into science classrooms.

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