

How Science Museum Can Support Science Teacher Professional Development for the New Science Curriculum

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Abstract

In August 2019, Taiwan released a new curriculum for the 12-year compulsory education. One of the key features of the new curriculum is the emphasis of skills or literacy rather than just the dissemination of content knowledge of specific discipline. The objectives of this study are to examine the role of science museum in supporting the new curriculum, in particular by organizing science teacher professional development workshops and evaluate science teachers' perception of the importance and teaching feasibility of the science literacy related lesson plans at the end of the workshops. Museum educators adopted case study approach in developing a series of lesson plans and each lesson plan represents one of the three scientific literacy developed by the museum curators. The study was conducted in the summer of 2014, 2018 and 2019. During a two-day workshop session, museum educators demonstrated the three lesson plans: Mathematics and plant forms (2014), genetic modified food controversies (2018), and the crisis of the Swedish warship VASA (2019) to teachers. At the beginning and the end of each session, teachers were asked to complete a survey about the perception of these lesson plans. Among the survey items are the importance of the literacy skills and teaching feasibility of these skills in the school setting. Pair t-test analysis revealed that, for the two indicators of all three lesson plans, post-participating perception of importance and teaching feasibility are significantly higher than the perception before participating the workshop, indicating that the design of these lesson plans may have an effect of changing teachers' perception of the teaching of literacy-based lessons. Additional analysis on teachers' opinion for the questions "I think students can learn literacy skills from this lesson" and "I will adopt this lesson in my future teaching" was very positive, indicating that teachers found the lessons from the workshop is useful for their students as well as have some impacts on teacher's future practice. This report will also discuss some directions for future research.

Keywords: Science education, science literacy, science case study, new science curriculum, teacher professional development

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Introduction

In August 2019, Taiwan released a new curriculum for the 12-year compulsory education. One of the key features of the new curriculum is the emphasis of skills or literacy across different disciplines rather than just the dissemination of content knowledge of specific discipline. This literacy-oriented pedagogy creates a challenge for current school teachers because they were trained in the more traditional way of delivering factual materials in the classrooms. So how can school teachers accommodate to the new curriculum and finding resources to help them achieving this demanding goal? In addition, teachers are usually occupied by the constant class progress in order to meet the requirement of an examination-oriented curriculum, and possible additional administrative works. Teachers constantly complain about the lack of time to develop interesting lesson plans for students, not to mention the development of lessons specifically for the new literacy-based classes. Science museums, with its rich diverse collections and strong research outputs, and without the constraint of the curriculum, can be an enormous learning resources for school science teachers by providing high quality literacy-based learning materials that science teacher can adopt in the school settings and making science learning more engaging for the students.

In fact, quick scan of the recent science education landscape may discover an interesting trend, that more and more studies show that informal learning environment such as museums, zoos, botanical gardens, aquariums and planetariums can play an important role in science learning. For example, the National Research Council of the National Academies of the United States revealed that throughout our live, more than 75% of the 16 working hours each day is engaged in the learning outside schools and science learning did take place in these informal science learning institutions (Bell et al, 2009). The Community for Advancing Discovery Research in Education (CADRE) of the United States also reported that the 21st century science and technology is too complex that no single K-12 school can do it all. The good news is that schools can work with the many informal science learning institutions across the country to bring the rich and diverse resources to classrooms, and engaging students in learning science (CADRE, 2012). Meanwhile, the Journal of Museum Education published a thematic issue on “Common Goals, Common Core: Museums and Schools Work Together” in October 2015. In this issue, many authors review the various ways museums collaborate with schools and report some successful case studies (Ng-He, 2015). When the United States released their Next Generation Science Standard in 2013, there was also a call for the science museum community to play a proactive role in helping school teachers to implement the next standard successfully (Short, 2014). In 2018, the larger museum community representative American Alliance of Museums released a statement along with major informal science education institutions urging the Congress to provide more funding in supporting informal STEM education and research (AAM, 2018). Among these initiatives, the most strong voice came from Andrea Ingram, Vice President of Education and Guest Services, Museum of Science and Technology in Chicago, who testified

before the U.S. House of Representatives Committee of Science, Space, and Technology Subcommittee that science museums can partner with STEM education by providing impactful programs that improve science engagement (Ingram, 2013).

Museums and schools collaboration or partnership is not new to museum practitioner. Traditionally, the best-known museum-school collaboration is through curriculum related field trips, after school, summer and weekend programs. But the collaboration can be extended to teacher professional development programs for practicing school teachers. This is where a science museum (some natural history museums categorize themselves as science museums) can offer their contributions. These museums have strong collection and research bases. It should be little effort for the museum's researchers to convert their research findings into real life case study lesson plans that teachers can use in their teaching. In fact, case studies had been widely adopted to help students learn science (Herreid et al., 2012; Llewellyn, 2005).

In this article, I am going to report how The National Museum of Natural Science developed literacy-based lesson plans and organized teacher professional development programs to introduce these lessons to current school science teachers in 2014, 2018 and 2019. Besides providing inspiring and practical lessons to ease the tension teachers feel about the soon to be implemented new curriculum, the author would like to examine teachers' attitudes toward the lessons learned from the workshops. In order to achieve this goal, I conduct a survey at the end of the workshops to collect teachers' response on the perception of the importance and teaching feasibility of these lesson plans, and their intention to adopt these lesson plans in future teaching.

The New Science Literacy

Any qualified science teacher is well aware of the fact that teaching science is more than presentation of scientific facts and the emphasis of knowledge acquisition. This type of teaching has a negative effect on science learning as students find the class boring and irrelevant to everyday lives. In addition, an overemphasis of knowledge (or just information) also affects student performance in international evaluation such as PISA (Programme for International Student Assessment) (e.g. Choi et al., 2011). In response to this, policy makers call for a revitalization of science teaching and putting efforts to incorporate skills-based learning such as science literacy into the future science curriculum.

As a major informal science learning institution, the National Museum of Natural Science responded to this call in late 2013 by working on a new science literacy framework through extensive literature review, numerous consulting meetings with science teachers, school principals, and parents. The resulting science literacy consists of three abilities with the aims to improve students' ability to 1) uncover the meaning beneath the scientific facts by making connections, 2) convert their knowledge into arguments, and 3) conduct an inquiry study.

For the first science literacy, the rationale is that most materials presented in schools are

fragmented and students rarely have the ability to connect this information within a single discipline or across disciplines to gain a deep understanding of the subject. In essence, making connections foster students to connect what is new to what is known from the past (Ritchhart et al., 2011). By doing so, isolated information progressively transformed into knowledge which can be used to provide solution to a situation and learning is no longer out of context. In order to achieve this goal, we need to develop students' ability to make connections of fragment scientific facts, and from these connections to see the relationships. These relationships may lead to the discovery of patterns, and finally, the big picture of these relationships and patterns will emerge. I truly believe at this stage of deep understanding, students will find that learning can be more meaningful (Nagle, 2013). The importance of this skill cannot be over-stated as interdisciplinary science learning is one of the major learning outcomes of the new curriculum.

Secondly, I think that our lives involve science and technology and many of these science related issues are controversial. In addition, our information overloaded cyberspace was flooded with many contradictory claims, which make the discussion of these issues even harder. Thus, as claimed by scholar that knowing a lot won't do you much good unless you have the ability to convert this information into your own argument and to identify and reject a false claim (Hillocks, 2010). Equally important, when faced with numerous evidences, we need additional skills to sort out and evaluate the order of these evidences (Rex et al., 2010). In fact, there has been repeated assertion that the goal of science learning is not just for the students to master the science concept but rather to acquire argumentative or reason with evidence skills which is essential in engaging in science discourse, and the teaching of argumentation skill have become a new benchmark in the teaching and learning science in order to meet the requirement of the Next Generation Science Standard (Sampson et al., 2013; Kuhn, 2010).

Lastly, the ability of conducting experiments to test the validity of competing hypothesis theories is the keystone of scientific progress. Any successful learning in science or complete understanding of the idea of science cannot be claimed without the demonstration of this skill. Though the nature of science (usually as one 50 minutes lecture) is taught as required in the science curriculum, many students don't have the opportunity to practice this skill, unless they are members of the science fair project team. Consequently, I would like to re-emphasize the important of inquiry study through experimentation. Here I focus on the ability to identify the key variables, then how to base on these context to design an experiment and collect relevant data and, finally, the interpretation and communication of the results. So, these are the three science literacy skills that the museum would like to communicate to science teachers.

The Study

In this section, I am trying to explain the adoption of case study approach and the development of representative case studies in related to the three science literacy skills in teaching science. I also

describe how the science museum organize and execute the teacher professional development workshops and finally, conduct the post-workshop survey of teachers' perception of the materials they learned from the workshops.

1. The Relevancy of Using Case Studies in Teaching Science

The adoption of case studies as a teaching tool has a long history in business, law and medical science fields. In these disciplines, prospective graduates usually find it difficult to apply what they learned in schools in real world situation to make sound judgement when facing conflicting information and uncertainty. As pointed out by O'Rourke (2000), students can memorize facts and procedures, and even occasionally guess the right answer in a multi-choice test. But students may not have a correct answer or solution to a situation they never encounter before. For example, these situations may involve decision on a difficult business expansion plan, dilemma in a law suit or the application of a novel medical therapy technology to treat a patient. By using case studies, students will be exposed to the challenge of real-world situations without definite solution, and during the process of analyzing these cases, students will learn important skills in critical thinking such as synthesizing, evaluating and applying knowledge they learned from classes. In fact, these skills correspond well to the higher learning of Bloom's taxonomy of learning domains (Herreid, 2012). In contrast to traditional lecturing, case studies contain many information other than text, usually come with historical description of the case, graphs and charts that students need to make meaningful connection in order to understand the case. In summary, it has been shown that incorporating occasional case studies in regular lecture could have positive impacts on students' ability in problem solving and decision making by using real event. In science, there are no shortage of such insightful cases that can provide students with great learning opportunity (e.g. Herreid et al., 2012, 2014).

2. The Three Lesson Plans

Summer 2014, An Interdisciplinary approach to Understand Forms in Nature with Mathematics. Fibonacci Number is a numerical series in which each number is the sum of the two previous numbers, such as 1, 2, 3, 5, 8, 13... Interestingly, there are many examples in nature conforming to this number series, the best-known examples include the seed arrangement of the sunflower head, scale arrangement of pine cone and pineapple and leave arrangement or phyllotaxis of certain plants (Ball, 1999; Steward, 1999). I develop this case with the aim to foster students' ability to make connections of different disciplines in order to gain an interdisciplinary perspective, and to uncover a relationship that may not be obvious with first glance, and a deep understanding of learning can be achieved. This ability represents the science literacy of uncovering meaning beyond the knowing of scientific facts (see above). The case begins with many examples of plant forms collected from nature, follow by the exploration of the Fibonacci number series in pineapple by counting clockwise and anti-clockwise to determine the arrangement of scales of pineapple. Among the many themes

explored in this case, one leading discussion question is how the sunflower solve a mathematical problem, given a confined circular space (the flower head), how sunflower pack its seeds in order to maximize its seed numbers which is an indicator of reproductive success in evolutionary terms. I then demonstrate the use of a computer program (another connection to other discipline) to simulate visually the various way the seeds arrange on the flower head. It turns out that the best solution (maximize seed numbers) follow the Fibonacci number Golden Ratio (a ratio obtained by dividing two consecutive Fibonacci numbers such as $5/8$). Finally, the same principle of Golden Ratio in solving sunflower's biological problem is extended to the field of architecture and Arts by examining famous architectural design and masterpieces of renowned artists. By making connections from math to life forms, the physics of constrain on growth and the employment of computer simulation to visualize these changes and finally to design and arts, this case truly represents an interdisciplinary study which can provide a deep understanding or big picture across a wide range of disciplines.

Summer 2018, Using Genetic Modified Food Controversies to Teach Argumentation: Genetic Modified Food (GMF) is a controversial issue across the globe. One of the safety concerns of GMF is the environmental impacts on non-target organisms such as butterflies. In 1999, a group of entomologists from Cornell University reported in the journal *Nature* the finding that after feeding larvae of butterfly on corn leaves sprinkled with pollen obtained from the nearby genetically modified corn field for 3 days, nearly 50% of the larvae died as compared to the control group (Losey et al., 1999). On the surface, the findings seem to support the claim that GMF is not safe for the environment and should be banned as most environmental protection groups advocated. And if you are the official of the Environmental Protection Agency (EPA) responsible for the licensing of the growth of the GM corn, what kinds of evidences or arguments do you need in order to make a sound decision? The design of this lesson plan emphasizes the importance of the ability of reasoning with evidence in scientific discourse. In fact, the EPA of the United States later called for six different groups of research laboratories across the country and Canada to conduct field experiments to verify the findings. The results of these field experiments were later published in the *Proceeding of National Academy of Science*. I find this historical scientific account highly relevant to the teaching of argumentation or reasoning with evidence, I then gather all relevant publications and develop into a case and presented in the workshop. In the workshop, I first presented the public concerns of GMF and the findings of the Cornell group. After that, I led the discussion of the reasoning of the various evidence needed. I used the Tables and Figures from these publications as handouts and let the participating teachers went through this information to reach their conclusion after group discussion.

Summer 2019, Using the Swedish Warship VASA Crisis to Teach Inquiry Study: In 1628, the Swedish warship VASA sunk at Stockholm harbor on its maiden voyage. In 1961, VASA was

surfaced and docked after 333 years in the dark harbor water. In 1990, a museum was established to house this historical ship and opened to the public. But in the summer of 2000, VASA showed its second crisis when curators discovered many white powdery spots on the surface of the hull. In depth analysis of the surface powders and core samples revealed that these are sulphate compounds at various oxidation states. It's claimed that the ship is under acid attacked from within and a truly chemistry time bomb (Gillon, 2002; Hamer, 2002; Sandstrom et al., 2002; Vogel, 2003). As we know today, VASA is still displayed in the museum and obviously, scientists have identified the problems and saved this warship from collapsing. This is a typical case of conservation science through a series of inquiry in which a problem is identified and the hypothesized causes is proposed and finally a predicted action is implemented to solve the problem. Again, this is a case with an emphasis on literacy skill of inquiry by continuous exploring numerous scientific inquiries. I started the case with a brief historical narration of VASA, then I lead the first inquiry question of how the wooden hull of VASA can be kept in good shape after more than 300 years down in the dark harbor water? Then the next inquiry proceeds to how can we get rid of the water embedded deep inside the wood of the ship without letting the ship to collapse? After VASA put on display in the museum, what caused the white powders on the surface of the ship and where does the acid come from and more importantly, what chemicals are involved in catalyzing this reaction? By understanding the underlying causes of these problems, we learn the way scientists solved this crisis. In essence, this case involves a series of hypothetico-deductive reasoning in the field of chemistry of acid-base balance, a subject most junior high school students already learned before. This case also high light that the significance of a seemingly basic knowledge can be applied in real world situation of preserving a historical warship.

3. Teacher Professional Development Workshop

In the summer of 2014 and 2018, The National Museum of Natural Science organized two Teacher Professional Development Workshops in each summer. In 2019, only one workshop was organized in the summer. The number of teachers participating these workshops range from 20-30 people. All the above-mentioned case studies were developed by the author and museum educators. Each of these case studies was developed corresponding to the science literacy criteria developed by the author.

During the workshops, the author first presented a lecture on the rationale of the newly developed scientific literacy. After that, museum educators will in-turn demonstrate the lesson plans to the teachers, which last for about 2 hours each. The design of each of these lesson plans was aligned to each literacy-skill mentioned above which are similar in many respects to the literacy skills requirement of the new science curriculum. The lesson plans were also very interactive and always prompting active involvement or expressing the viewpoints from the teachers. Thus, teachers were advised to play a role as students and were invited to participate in the discussion of these lesson plans. After

completing these workshops, teachers will be eligible to loan these lesson plans with relevant specimens and teaching guidelines to their school through a dedicated website for the workshop. Our ultimate goal is to effectively convert the rich and diverse learning resources of the museum to interesting lesson plans that are science literacy relevant and could be widely adopted in the school settings. As for target students, I developed these lesson plans for students from grade 8-12 in mind. In fact, there are quite a few elementary science teachers participated in the workshops, we also discuss the possible ways to customize the lessons for younger students.

4. Data Collection and Analysis

This study was conducted in the summer of 2014, 2018 and 2019 as the museum organized these two-day workshops. At the beginning and the end of these workshops, all participants were asked to complete a survey instrument to examine their viewpoints or perceptions about the lesson plans in order to examine possible changes in their opinions after participating these activities. The instrument contained many items related to the lesson plan, among these, such as time allocation for the lessons, the smoothness in delivery the contents and completeness of the lessons. But for the present study, only two major indicators, the importance of the science literacy skills and the teaching feasibility of these skills in school, were used in the analysis. For each question of the instrument, a 10-point Likert scale was used to collect participants' responses, with higher score represent higher perception of importance and teaching feasibility. In addition, in the 2018 and 2019 studies, I added two more questions related to teachers' opinion that their students can learn the literacy skills from the lessons, and teachers' intention to adopt these lessons in their future teaching in schools (as asked by these two questions: "I think students can learn science skills from this lesson plan", and "I intent to use this lesson plan in my future teaching").

I used SPSS to analyze the data, particularly pair t-test analysis to examine the differences of change of perception of the two major indicators. I also used descriptive statistics to show teachers' rating of their response in including the literacy skills in future teaching.

Results and Discussion

Getting people to change their practices is a difficult task if not impossible. The reasons for this are many, but first, I think people may perceive that changes are irrelevant or unimportant and secondly, they consider the proposed changes are not feasible in practice, though sound in theory. So the first objective of this study is to examine the possible teachers' perception changes of the importance of the proposed science literacy skills as well as the feasibility of teaching such skills in schools, after the teachers were introduced to these skills in the workshops organized by the museum. For all workshops from 2014, 2018 and 2019, pair t-test analysis for the differences in perception before and after participating the workshops revealed that there is significant difference for both the importance and teaching feasibility of the literacy skills, with the post-workshop perception

scores significantly higher than the pre-workshop perception scores. These differences are significant for the three lesson plans (Table 1). These results indicated that the design of these lesson plans did have an influence on teachers' perception of changes on the importance and teaching feasibility of literacy-related skills in classrooms. In fact, Herreid (2012) argued that with well-designed lesson plans such as science case studies, these literacy-based learning can progressively develop into habits of mind, and these skills can really be taught. In addition, analysis on the question "I think students can learn literacy skills from this lesson plan" in the GMF Controversies and VASA Crisis lessons showed that the two highest scores account for 80% and more than 63% respectively for all responses (Figure 1). Similar results are obtained for "I intent to use this lesson plan in my future teaching", with the two highest scores accounts for 75% of all response for the GMF Controversies lesson, while almost 50% of teachers express the intention to use the VASA Crisis lesson in their future teaching (Figure 2). From these results, it's reasonable to assume that as long as there are well designed lessons, teachers will have more confidence in teaching of literacy related skills and thus changes of practice are possible. These findings demonstrated that teachers perceived the literacy-related lesson plans (interdisciplinary lesson, argumentation, and inquiry) presented in these workshops are worthy and considering adopting in their future practices.

Over the last two decades, there have been a trend to move toward a reform of science education across the globe. As Osborne (2007) argued that the current science education was rested on value of no merit and this practice also have a negative effect on students' attitude toward science. One of the objectives of this wave of reform is the emphasis of scientific literacy, which educators believed that it's the skills students should learn in contemporary society in the twenty first century (Choi et al., 2011; Osborne, 2007). At the same time, there is also substantial voice from the informal science education community that museums can contribute in this education reform (AAM, 2018;

Table 1. Comparison of the Importance of Literacy Skills and Teaching Feasibility of Literacy Skills before and after the Workshops

	Importance of Literacy Skills (Mean, SD)			Teaching feasibility of Literacy Skills (Mean, SD)		
	Before the workshop	After the workshop	Paired-t test	Before the workshop	After the workshop	Paired-t test
Math and Plant Forms (2014)	6.74, 1.69 (n=65) ¹	8.69, 1.13	-11.37 <i>p</i> =0.000	6.70, 1.49 (n=63)	9.16, 0.75	-12.74 <i>p</i> =0.000
GMF Controversies (2018)	8.08, 1.55 (n=39)	9.33, 0.89	-5.72 <i>p</i> =0.000	7.13, 1.79 (n=39)	9.00, 1.07	-5.99 <i>p</i> =0.000
VASA Crisis (2019)	7.29, 1.69 (n=17) ²	9.00, 1.00	-5.18 <i>p</i> =0.000	7.12, 2.15 (n=17)	8.35, 1.46	-3.11 <i>p</i> =0.007

Note to sample size:

¹ In 2014, the workshops were supported by funding from the Ministry of Education and was free to all participating teachers. The workshops became a pay-program beginning from 2016. There were a drop in the number of participants to an average of 20 for each workshop.

² Only one workshop was organized in the summer of 2019.

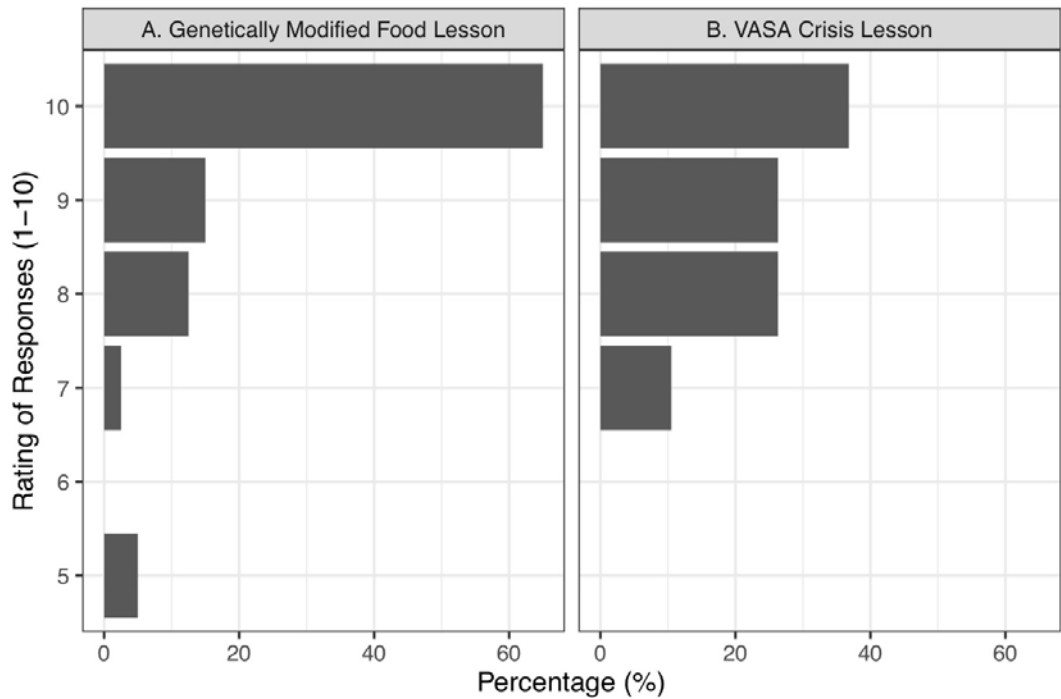


Figure 1. Teachers' response to the question "I think students can learn literacy skills from this lesson"

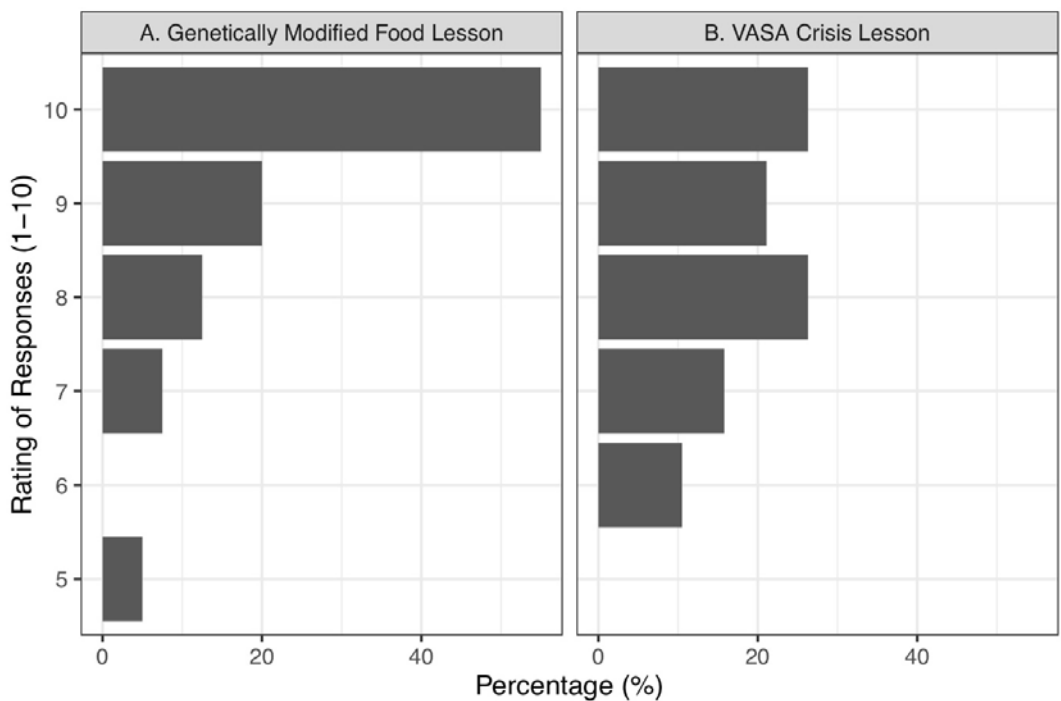


Figure 2. Teachers' response to the question "I will adopt this lesson in my future teaching"

Short, 2014; Ingram, 2013). Uyen Tran (2008) also asserted that the provision of scientific literacy is no longer the exclusive preserve of schools. This report documents how science museum can help school teachers to implement the literacy-based new curriculum by organizing teacher professional development programs so teachers can retool themselves to meet the requirement of the new standard. Even though the science museum community have provided similar professional development programs for teachers over the years (e.g. Ingram, 2013; Short, 2014), this report is the first exploratory study to examine the changes of perception about the importance of literacy-based lessons and more importantly, the demonstration that the teaching of scientific literacy is possible in secondary science classrooms.

In preparing these lessons for the last six years, the author also identified several forces work against the teaching of literacy-based lessons in the classrooms. For interdisciplinary teaching, it's quite a common perception among school administrators and teachers that the teaching of these lessons wouldn't necessary improve the admission rate of getting into colleges. In addition, teachers don't have the confidence of teaching interdisciplinary lessons because they may not be good at other subject areas, such as a biology teacher to teach physics related materials (Nagle, 2013). As for the teaching of argumentation, it had been argued that its underutilization could be related to the lack of pre-service teacher instruction on how to implement in the classrooms (Richmond, 2017), and once sufficient instruction is provided to teachers, they are more likely to use argumentation in the classrooms (Demircioglu and Ucar, 2012). In fact, this is exactly the reason why the author developed argumentation related case studies every workshop, I truly believe that once teachers familiar with the ideas and with well-designed supporting materials, they will fill more confidence in using it in future teaching. It's also interesting to note that although teachers gave high rating to the two lessons in 2018 and 2019, in terms of students can learn literacy skill and intention to adopt the lessons, the argumentation-based case GMF controversies receive higher rating than the VASA crisis case (Figure 1 and Figure 2). On the practical side, it's almost impossible for teachers to teach argumentation from materials directly from textbooks and beginning from scratch. This situation further strengthens the use of case studies in science classrooms by demonstrating to students that how science actually works. As for the time allocation for the teaching of these science case studies developed by the museum educators, the author learned from informal conversation with teachers during the workshops that the good news is that for the implementation of the new curriculum, there are two free time slots every week that teachers can be used to introduce the lessons they learn from the workshops.

In conclusion, a science museum, such as The National Museum of Natural Science, with its rich and diverse collections and research potential, shouldn't be absent in the current wave of science education revitalization. The museum believes that only when teachers get acquainted through these workshops with the latest development in science education, such as the new curriculum which focus more heavily on developing students' critical thinking skills over the more traditional content-based

learning, the quality of science education will eventually be improved. However, the author conducted the survey shortly after the workshop when there is still fresh memory of new thing learned, we cannot be certain how long these enthusiasms be sustained by the teachers. A long-term follow-up on site observational study conducted in schools and in-depth interview with teachers to explore the reasons to adopt or not to adopt these skills in teaching will be necessary in order to answer this question (e.g. Simon et al., 2006). Finally, I understand that science museums are not at the position to foster the implementation of these lessons in the schools, but just want to show teachers the availability of high-quality science lessons and continue to contribute museum's effort in the current science education reform.

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科學博物館如何在新課綱下支援科學教師的專業發展

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摘要

2019年8月，臺灣的12年義務教育正式推出108新課綱。新課綱的特色之一是強調學生的素養能力，而非只是傳授各學科的領域知識。本研究目標是探討科學博物館如何支援新課綱，特別是透過教師專業發展工作坊介紹有關科學素養的教案，並針對老師在參加工作坊後，對這些教案在科學素養的重要性的教學現場的教學可行性進行評量。博物館教育人員採用科學個案發展一系列的教案，每個教案的規劃都依照由博物館研究人員所發展的3個科學素養中的其中一項進行設計。本研究是在2014、2018和2019年夏天進行。在兩天的工作坊中，博物館教育人員分別向老師示範3個教案，包括：數學與植物型態的費伯那奇系數(2014)、基改食物爭議(2018)和瑞典古戰艦VASA的保存危機等(2019)。在工作坊開始和結束時，會請老師填寫一份有關這些教案想法的問卷。問卷的題目眾多，但本研究只分析其中兩個指標：老師認為教案所提及的科學素養的重要性的未來在學校教學的可行性。成對t檢定分析發現，針對這兩個指標，老師在參加工作坊後的評量分數都顯著高於參加工作坊前的分數，顯示這些教案的設計有助於老師教授以素養為基礎的課程。此外，關於「我認為學生能從本教案獲得科學學習技能」和「我願意使用本教案作為日後教學的內容」這兩個題目，老師的回應也都十分支持，顯示老師認為工作坊的教案對學生學習科學素養是有幫助的，並且對老師未來的教學實踐也有正面影響。本研究最後也會探討一些未來的研究方向。

關鍵詞：科學教育、科學素養、科學個案、108課綱、教師專業發展

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