教育部113年度中小學科學教育計畫專案

期中報告大綱

計畫編號：
計畫名稱： 建構融入科學史與科學哲學的科學教育課程
主 持 人 ： 李偉廷
執行單位： 臺中市立沙鹿國民中學

壹、 計畫目的及內容：

科學史與科學哲學對科學教育的益處在過去的許多文獻中都有提及，然而現今的課程綱要之中對於科學史與科學哲學的篇幅仍然相對缺乏。因此本研究試圖透過系統性文獻分析方法，結合科學博物館的資源，梳理科學史與科學哲學的架構（研究一）；並嘗試將這個架構結合在現今的科學教育課程綱要之中（研究二）；此後進一步組織教師專業社群，透過社群的腦力激盪與討論互動，發展基於科學史與科學哲學的課程模組，並且嘗試建構課程發展模式（研究三）；最終透過所發展的課程模組進行教學，以問卷、訪談、課堂觀察與實作成品進行學生的學習成效評估（研究四）。本研究期望能透過博物館、教師與學校之間的互動關係，結合制式教育與非制式教育資源，強化科學學習生態系統（李偉廷、謝百淇，2019），產出融入科學史與科學哲學的科學教育課程，以達成十二年國民基本教育課程之中關於素養的核心目標。

貳、 研究方法及步驟：

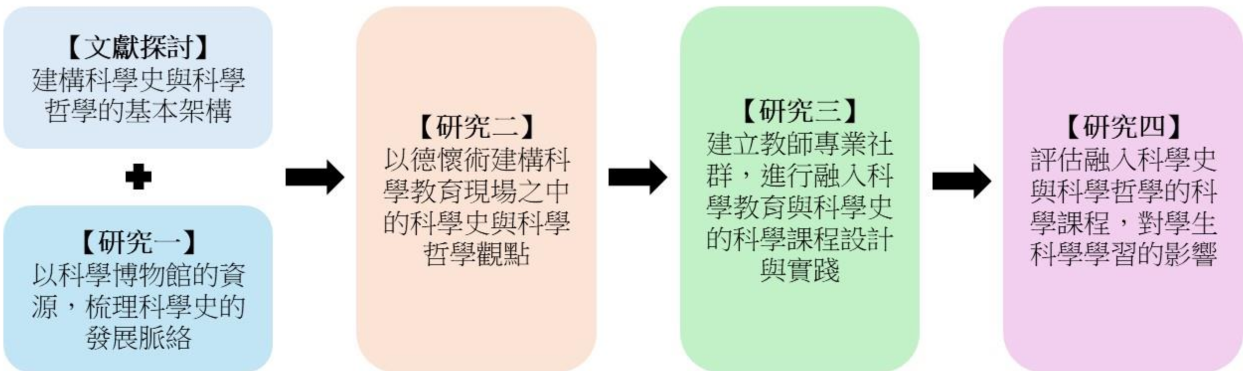

圖1 研究架構圖

本研究分為四個子研究依序進行，研究架構如上圖1所示。研究一以科學史為主軸，透

過科學博物館的資源進行科學史的脈絡梳理，並連結文獻探討的結果，產出科學史與科學哲學的初步脈絡。研究二則是接續研究一的成果，將科學史與科學哲學的脈絡與科學教育進行連結。研究三則是進一步透過專家教師形成教師專業社群，進行融入科學史與科學哲學的科學課程發展。研究四則是在課程發展完成之後進行學生學習營隊，以量化指標與質性表現作為學生學習成效，透過課程實際評估學生的學習狀況。四個子研究的具體研究設計如下所述。

【研究一】以科學博物館的資源梳理科學史的發展脈絡

科學博物館有豐富的館藏資源，能夠以實物展品的方式，呈現科學史上的重要節點及發展脈絡。本研究將與國立自然科學博物館（以下簡稱科博館）合作，科博館過去對於科學史的脈絡分析有相當豐富的經驗。研究者曾與之合作，以人類文化廳的重要展品：水運儀象臺，配合中國古代文獻資料，以這些資料作為節點，串聯整體的科學史發展脈絡，並且與現今科學知識連結。有鑑於此，本研究與之持續合作，透過科學史上的重要實物展品進行科學史的發展脈絡梳理，包含但不限於中國的科技與文明為範圍。具體而言，本研究將以科學史上重要文獻與博物館展品為載體、以博物館員與研究者組成之研究團隊為研究工具，透過質性系統文獻回顧研究法（穆佩芬，2014），進行科學史的發展脈絡梳理，並形成博物館內展品的科學史發展脈絡，以作為後續結合科學教育的重要基礎。

具體而言，本階段預計辦理4場次討論會議，並邀請相關專家學者出席擔任諮詢委員，針對文獻與展品背後的科學史脈絡進行討論，並提供研究團隊修正與調整之建議。

【研究二】以德懷術建構科學教育現場的科學史與科學哲學

本研究透過文獻探討梳理自二十世紀以來的科學哲學觀點，並基於研究一關於科學史發展脈絡的研究結果，形成對科學史與科學哲學的基本架構，接著本研究試圖進一步促持科學教育、科學史與科學哲學之間的互動。因此本研究邀請在科學教育已有深厚基礎，且據研究團隊所知，在科學課程中曾有意或無意間結合科學史與科學哲學的教師進行德懷術（Linstone & Turoff, 1975）研究，以了解現今科學教師對於科學史與科學哲學的看法，並且進一步以專家共識的方式建構各學習階段的科學教育綱要中的科學史與科學哲學觀點，以作為下一階段課程發展的基礎。

具體而言，本階段預計邀請國小、國中及高中各階段之科學教師參與德懷術研究，各階段以邀請20位教師為原則，透過輔導團及學科中心協助招募教師參與，透過反覆的問卷調查與數據分析，尋求教師之間對於科學教育綱要中的科學史與科學哲學的最大共識。此階段的問卷為求謹慎並考慮回收率等問題，故採用紙本問卷郵寄的方式進行發放與回收。

【研究三】以教師專業社群發展融入科學史與科學哲學的科學課程

透過文獻探討、研究一與研究二的成果，本研究進一步將理論轉化為實踐方案。因此本研究將進一步邀請參與德懷術研究（研究二）的教師組成教師專業社群，透過社群定期實體與線上討論共備，發展融入科學史與科學教育的科學課程。除了課程設計之外，為使課程未來能轉化並落實到不同學校，因此也會對於課程所需要的教材、教具、影音媒體、材料包以及補充資源等素材有充足的準備，形成完整的教學模組。並且透過同儕觀議課對於課程進行精進，期望在正式進行課程之前，能對於課程有高度的準備，以利正式課程的進行。

基於以上目標，本階段預計針對每一個教學模組進行2次實體會議及2次線上會議，透過教師之間的互動與激盪，以科學史與科學哲學為基底，並以科學課程為載體進行課程發展。本研究預計發展2個科學課程模組，分別以中國科學與西方科學的脈絡作為課程的主軸，並引發教師進一步思考中國科學與西方科學在科學史與科學哲學的脈絡上有何本質上的差異。

此外，本階段亦期望能透過觀察教師與研究團隊在社群中的參與及討論過程，整理出教師專業社群在與非制式教育機構（科學博物館）之間的互動機制，以作為未來制式教育與非制式教育合作的參考。

【研究四】評估融入科學史與科學哲學的科學課程對學生學習成效的影響

在完成課程設計之後，必然要透過實際授課來評估課程的成效（黃淑玲，2013）。因此，本研究在課程模組完成之後，將透過學生營隊來進行教學，並且透過量化問卷、質性訪談與課堂觀察等方式收集學生學習成效的資料。量化問卷將以前、後測的方式測量學生的知識層面變化，質性訪談將用以測量學生的態度層面變化，而課堂觀察將作為學生技能層面改變的評估依據。

辦理學生體驗活動課程時間如下表所示：

場次	對象	課程時間	參加人數
1	國小五、六年級	上午 9 時至下午 4 時 30 分(8 節課)	學生 24 人
2	國小五、六年級	上午 9 時至下午 4 時 30 分(8 節課)	學生 24 人
3	國中一、二、三年級	上午 9 時至下午 4 時 30 分(8 節課)	學生 24 人
4	國中一、二、三年級	上午 9 時至下午 4 時 30 分(8 節課)	學生 24 人
5	高中一、二、三年級	上午 9 時至下午 4 時 30 分(8 節課)	學生 24 人
6	高中一、二、三年級	上午 9 時至下午 4 時 30 分(8 節課)	學生 24 人

具體而言，本階段將以量化數據為主，輔以質性資料作為佐證，了解學生在參與融入科學史與科學哲學的科學教育課程之後，其知識、技能與態度層面是否有所變化，並作為研究三所發展之課程的成效評估。

綜合以上的四個子研究，本研究將以 SPSS 進行描述性與推論性統計分析，並以 Amos 輔助進行量表效度檢驗分析，在質性資料方面，預計將透過 NVivo 協助資料分析與呈現。

此外，由於本研究涉及博物館員、教師及學生，參與研究的人員相當多元，研究者對參與者的保護機制設計相當重要，因此本研究計畫將申請人類研究倫理審查，以強化研究團隊的研究倫理意識，也確保研究參與者的權益。倫理審查通過證明如下所示。

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研究倫理審查核可證明書

計畫名稱：建構融入科學史與科學哲學的科學教育課程
案件編號：202411ES021
校/系/計畫主持人：臺中市立沙鹿國民中學/教務處/李偉廷教師
計畫書版本/日期：Version 1/ 2024-11-18
知情同意文件版本/日期：Version 2/ 2024-11-22(S)；Version 2/ 2024-11-22(T)
案件類型：微小風險審查案件
審查聲明：本案若有疑義，經研究倫理審查會決議，本會有權撤銷本案核可證明。
通過日期：西元2024年11月26日
有效期間：西元2024年11月26日至西元2025年07月31日止
※計畫內容若有任何修改，或增加招募人數，應申請變更審查通過後，始得實施。
※本案應於核可證明屆期前申請持續審查通過，方可繼續執行。並應於核可證明屆期後三個月內，申請結案審查。

國立臺灣師範大學研究倫理審查委員會
主任委員
蕭惠貞
西元2024年11月26日

蕭惠貞 (代)

Certificate of REC Approval

Proposal Title: Developing Science Education Curriculum Incorporating History and Philosophy of Science
REC Number:202411ES021
University/Dept./Principal Investigator: Taichung Municipal Sha-Lu Junior High School/ Office of Academic Affairs/ Teacher Wei-Ting Li
Project Version/Date: Version 1/ 2024-11-18
Informed Consent Document Version/Date: Version 2/ 2024-11-22(S)；Version 2/ 2024-11-22(T)
Type/REC Announcement: Expedited Review
NTNUREC retains the right to revoke the approval before the final endorsement by board.
Approval Date: November 26, 2024
Effective Period: November 26, 2024 to July 31, 2025
※Amendments should be submitted to REC before implementation if there are any changes to the approved protocol, including increasing participant enrollment.
※Continuing Review Applications should be submitted to REC before the current approval expires. The final report should be submitted within 3 months after expiration.

Huichen S. Hsiao   Huichen S. Hsiao (deputy)
Chair
Research Ethics Committee
National Taiwan Normal University
November 26, 2024

參、 目前研究成果：

根據研究進度圖，截至2月為止，應完成【文獻探討】、【研究一】與科學博物館梳理科學史脈絡、【研究二】科學史與科學哲學德懷術研究，分述如下。

【文獻探討】

1. Nature of Science

Philosophical perspectives on the NOS have evolved over time, and even within the same era, multiple philosophical viewpoints may compete for dominance. Abimbola (1983) suggested that the philosophy of science can be categorized into traditional views such as logical empiricism, rationalism, and positivism; modern views like post-positivism; and transitional views situated between the modern and traditional, such as falsificationism. Given the complex and multifaceted nature of the philosophy of science, and the lack of a definitive consensus, it is crucial for science educators to present a balanced view of the NOS. Overemphasis on any single perspective should be avoided (Loving, 1997). Science teachers should be knowledgeable about the diverse stances of different philosophical viewpoints while also seeking a balanced approach that is suitable for the specific learning level of their students.

From the past to the present, the NOS has been a fundamental cornerstone of science education (Khishfe, 2023). Project 2061 has emphasized that science education should cultivate scientifically literate citizens, and one way to achieve this is by enhancing students' understanding of the NOS (AAAS, 1989). Therefore, the NOS is crucial and essential for both teachers' science instruction and students' science learning. However, the definition of the NOS is quite diverse and divergent, and scientists have yet to reach a consensus. Nevertheless, we can still find some clues from the content of the NOS proposed by some well-known organizations.

The National Science Teaching Association (NSTA) considers NOS to be a part of scientific literacy, which can strengthen students' understanding of scientific knowledge and enable them to make informed decisions when faced with science-related issues (NSTA, 2020). It encompasses the following aspects: the tentativeness of scientific knowledge, the nature of scientific inquiry, the goals of science, and the relationship between science and society. The American Association for the Advancement of Science (AAAS) argues that fields like physics, biology, and psychology have a long history of developing solid, well-tested ideas. These ideas have given us a much better understanding of the world. To reach these conclusions, scientists rely on a process that involves observing, thinking critically, experimenting, and verifying results. These methods are the core of the scientific process and set science apart from other ways of knowing (AAAS, 1989). The AAAS breaks down the NOS into three main parts: the scientific worldview (the basic beliefs that guide scientific work), scientific inquiry (the characteristics of scientific methods), and the scientific enterprise (how science interacts with individuals, organizations, and society).

As we entered the 21st century, the world has been changing at an accelerated pace. Science has taken on an increasingly prominent role in our lives, and contemporary society is grappling with a myriad of science-related issues. Consequently, many organizations have raised questions about whether the NOS has evolved to address these modern challenges.

In their book, A Framework for K-12 Science Education, the National Research Council highlights that scientific and engineering practices are crucial for students to understand the NOS (NRC, 2012). While these practices often emphasize firsthand skills, they also mirror the problem-solving approaches employed by scientists. Therefore, when students grasp these NOS, they can better approximate the thinking and behaviors of scientists.

The Organisation for Economic Cooperation and Development (OECD) launched the Future of Education and Skills 2030 project in 2015 (OECD, 2015), emphasizing the importance of developing competencies in students. The goal is to equip students with the knowledge, skills, attitudes, and values needed to become active, responsible, and engaged citizens. Building upon this, the PISA 2025 Science Framework highlights the significance of teaching the NOS to achieve scientific literacy (Lederman, 2006), particularly through instruction that encompasses both procedural knowledge and epistemic knowledge (OECD, 2023).

In line with international trends, Taiwan has not been an exception. The Grade 1-9 Curriculum Guidelines (Ministry of Education, 2003) incorporated learning objectives related to the nature of science and technology, introducing students as early as the first grade to the fundamental concepts of scientific knowledge, including scientific methods, laws, and reliability. More recently, the Curriculum Guidelines of 12-Year Basic Education explicitly stated that students should develop an understanding of the NOS and recognize the interplay between science and society (Ministry of Education, 2018).

NOS is a complex and multifaceted concept that has been a subject of philosophical debate for centuries. While there is no single definition, various perspectives and frameworks have emerged over time. Key aspects of the NOS include the tentativeness of scientific knowledge, the role of scientific inquiry, the goals of science, and the relationship between science and society. A balanced understanding of these aspects is crucial for science education, as it empowers students to become scientifically literate citizens capable of making informed decisions in a science-driven world.

2. The Nature of Science as a Multidimensional Construct

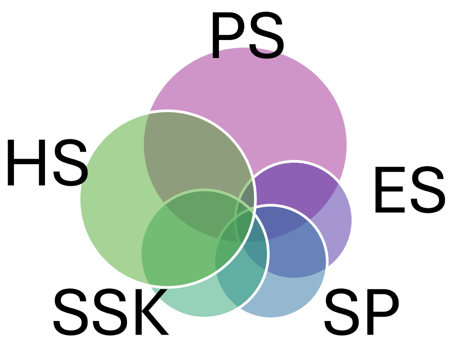
The nature of science, encompassing its definition, understanding, and content, is a central issue in science education. The scope of the nature of science extends beyond scientific outcomes to include the processes that generate science. Science possesses a unique mode of inquiry that emphasizes evidence and creativity (Archibald, 1989). Moreover, the nature of science is crucial for cultivating scientific literacy (Lederman, 2013). In the 21st century, where scientific literacy is highly valued, integrating the nature of science into science education can help students develop the competitiveness needed to face future challenges (Turiman et al., 2012) and enhance their learning motivation, interest, and engagement (Millar, 2006). Investigating the nature of science can also foster scientific development through reflection on the scientific research process (Shi, 2020) and promote interdisciplinary collaboration and interaction. Science should not be confined to laboratory knowledge but should strive to address societal challenges such as pseudoscience and socio-scientific issues. The foregoing arguments demonstrate that exploring the nature of science is not only significant for science education and development but also empowers us to become scientifically literate citizens better equipped to address contemporary societal challenges (Dagher & Erduran, 2016).

However, research by previous scholars has revealed that the nature of science is quite diverse. Many scholars have attempted to analyze the meaning and structure of the nature of science. For example, the consensus view proposed by Lederman et al. (2002) has been the dominant framework for the past few decades. This framework emphasizes the core characteristics of science, such as being empirical, tentative, theory-laden, creative, and imaginative, socially, and culturally embedded, involving inference and theoretical entities, and being based on scientific theories and laws. While this framework seems comprehensive, it has been criticized for its lack of attention to cultural and social aspects (Erduran & Dagher, 2014). Furthermore, Allchin (2011) argues that Lederman et al.'s view lacks an exploration of the nature of dynamic scientific practices from the perspective of historical changes in science. However, earlier, Longino (1990) proposed a conceptual framework that views science as a form of social knowledge, emphasizing that science is not only an objective cognition but also a practice that grows out of social and cultural contexts.

In recent years, some scholars have argued that the psychology of science should be incorporated into the framework of the nature of science (Feist, 2006). This argument stems from the belief that scientific thinking, as it relates to scientific reasoning, experimental design, inductive and deductive reasoning, problem-solving, and even the representations used (Fuchs & Evans, 2012), can vary and lead to differences in the nature of science itself (Feist, 2008). Furthermore, by incorporating sociological perspectives into the psychological foundation, we can better understand how scientific knowledge evolves through the dynamic interactions of groups of scientists (Hull, 1990).

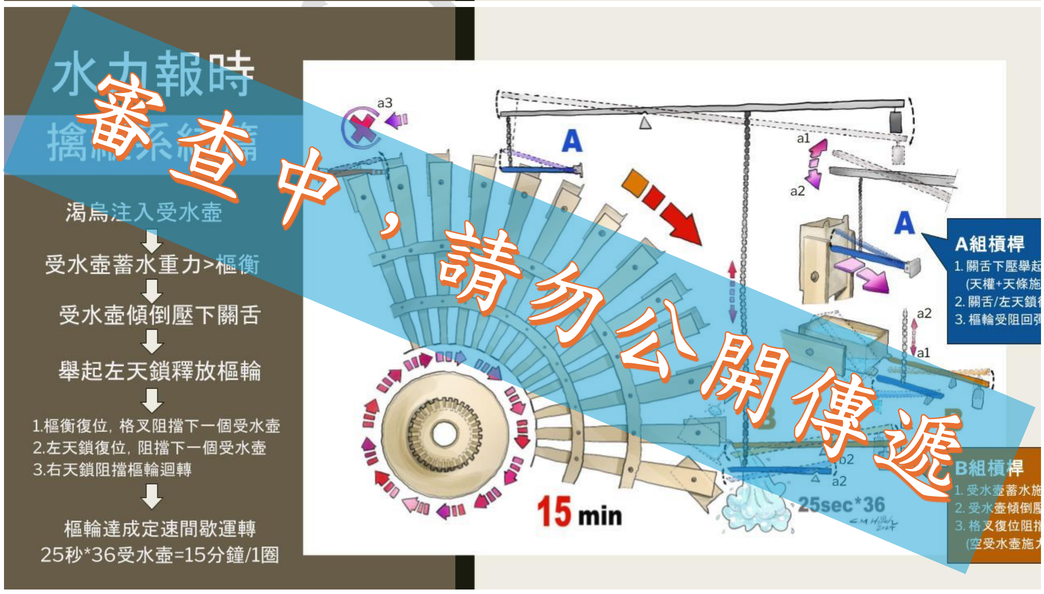
Since the scientific revolution of the 17th century, rapid advancements in science have brought many conveniences to human life, but they have also led to the problem of institutions and laws struggling to keep pace with scientific developments, and have given rise to ethical issues (Douglas, 2009). Examples include human biological experiments during wartime, the collection and analysis of genetic information, biological cloning technology, and global environmental changes. These all involve conflicts between science and ethics. If we are to consider human scientific behavior within the framework of ethics, we must view humans as part of the natural whole, and the protection of every individual in the natural world (including humans themselves) becomes a responsibility rather than free will. This reflection was first proposed by Heidegger (1977) and was further developed by his student Jonas. Jonas (1979) advocated an ethics that opposes anthropocentrism, but also acknowledged the special place of humans in the natural world and argued that humans must consider their responsibilities when interacting with nature, especially their responsibilities to future generations. This perspective aligns with the Sustainable Development Goals issued by UNESCO (2015).

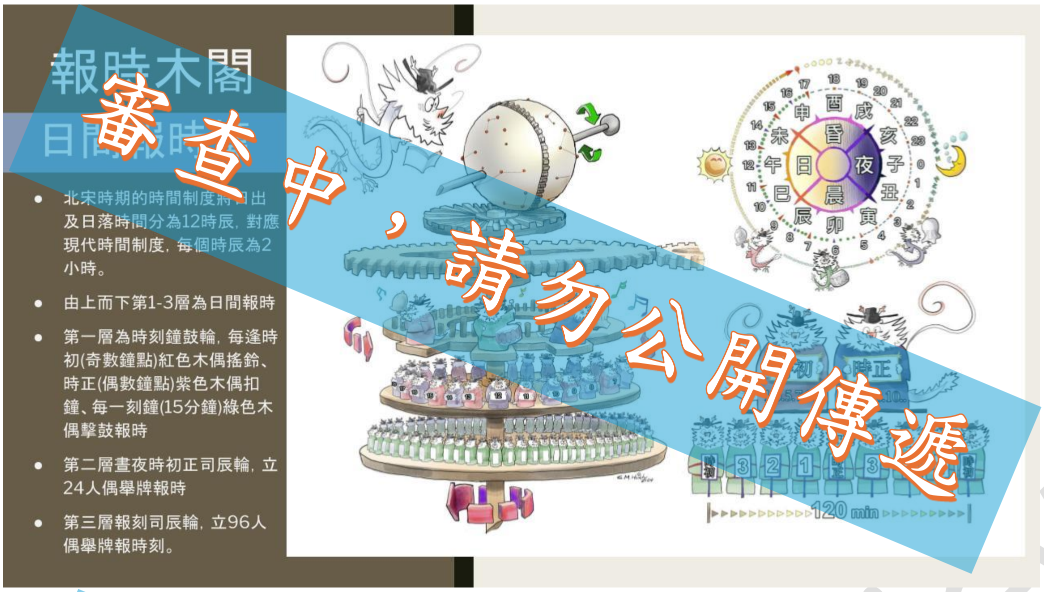
Previous studies have revealed a consensus among scholars that the nature of science is complex and multifaceted, requiring an interdisciplinary perspective (Harrison et al., 2015). However, the exact boundaries of this concept remain elusive, with various disciplines contributing to our understanding. Given the diverse nature of science, this paper will explore the integration of philosophy, history, sociology, psychology, and ethics to construct a comprehensive nature of science framework for science education.

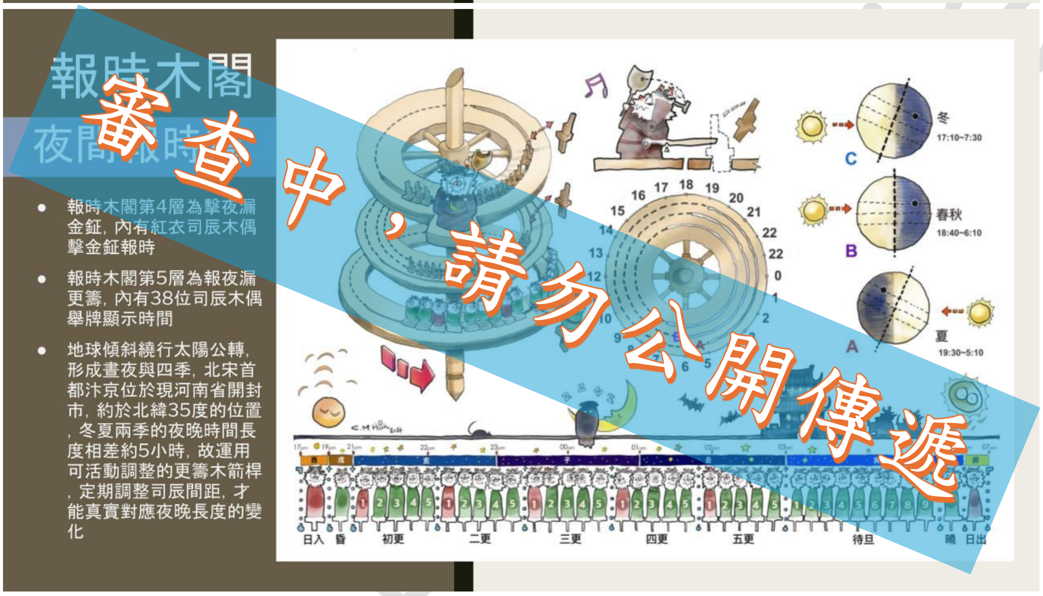


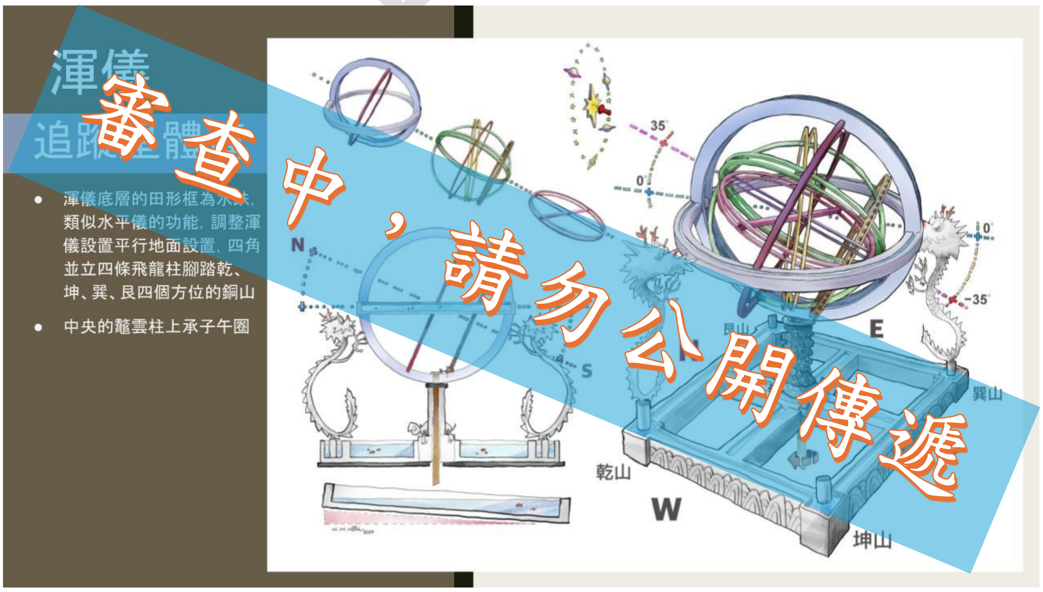
*PS=philosophy of science; HS=history of science; SSK=sociology of scientific knowledge; SP=scientific psychology; ES= ethics of science.

【研究一】與科學博物館梳理科學史脈絡




報時木閣
日間報時
北宋時期的時間制度
及日落時間分為12時辰，對應現代時間制度，每個時辰為2小時。
由上而下第1-3層為日間報時
第一層為時刻鐘鼓輪，每逢時初(奇數鐘點)紅色木偶搖鈴、時正(偶數鐘點)紫色木偶扣鐘、每一刻鐘(15分鐘)綠色木偶擊鼓報時
第二層晝夜時初正司辰輪，立24人偶舉牌報時
第三層報刻司辰輪，立96人偶舉牌報時刻。
申 酉 戌 亥 子 丑 寅 卯 辰 巳 午 未
昏 夜 晨 日
初 正
120 min


報時木閣
夜間報時
報時木閣第4層為擊夜漏金鉦，內有紅衣司辰木偶擊金鉦報時
報時木閣第5層為報夜漏更籌，內有38位司辰木偶舉牌顯示時間
地球傾斜繞行太陽公轉，形成晝夜與四季，北宋首都汴京位於現河南省開封市，約於北緯35度的位置，冬夏兩季的夜晚時間長度相差約5小時，故運用可活動調整的更籌木箭桿，定期調整司辰間距，才能真實對應夜晚長度的變化
冬
17:10~7:30
春秋
18:40~6:10
夏
19:30~5:10
C
B
A
日入 昏 初更 二更 三更 四更 五更 待旦 曉 日出


渾儀
追蹤星體
類似水平儀的功能，調整渾儀設置平行地面設置，四角並立四條飛龍柱腳踏乾、坤、巽、艮四個方位的銅山
中央的鼇雲柱上承子午圈
35°
0°
-35°
N
S
E
W
乾山
坤山
巽山

【研究二】科學史與科學哲學德懷術研究

共計完成3次德懷術問卷研究，計有14位教師參與德懷術專家小組。經過一次質性問卷及兩次量化問卷的資料收集與整理之後，本研究產出科學本質觀點如下。

編號	敘述
PS01	知識應建立在證據、假設和模型之上，且基於新的證據來修正原本的知識
PS02	科學的探究精神是有系統的解決問題方法，可以辨認出問題的可能原因
PS03	以科學方法進行問題解決的步驟包括觀察、提問、蒐集資料、假設、探究活動、分析和結論
PS04	了解科學知識的形成方法，並接受科學方法可能會受到的限制
PS05	針對現象進行提問，並以嚴謹的邏輯論述原因
PS06	清楚的定義科學問題，並設定控制變因、操作變因與應變變因
PS07	訓練學生科學認知、探究能力、科學的態度與本質，並應用於生活中
PS09	科學是研究自然的知識系統，並是許多探究成果的集結
PS10	理性思考、觀察判斷問題、設計解決方法、詳細記錄並視結果持續精進
HS02	以實例說明科學如何一棒接一棒奠定基礎
HS03	從科學家的故事學習生活中學習解決問題的過程及其研究精神
HS05	科學史的發展應著重在整個大方向的發展及演進，並結合知識的學習傳遞給學生
HS07	介紹各時期對於自然現象的解釋，以及各時期理論之缺陷，後續又如何修正這些缺陷
SSK01	科學無法完全脫離文化而生存，受生活經驗、社會文化背景影響，且反映文化的需求
SSK03	了解科學不僅是合作，也有競爭
SSK04	強調科學對於性別在資源及機會上的平等
SSK05	科學邏輯思辨有助於解釋社會現象，並掌握對資訊的識讀能力
SSK06	科學發展推動文化與技術的進步與更新
SSK07	科學知識的傳播使全球的知識體系趨於一致，也導致地方傳統知識的流失
SSK08	科學牽涉人類發展脈絡，人類需求會推動科學發展，而科學發展也會改變人類發展
SSK09	可以從科學發展過程探討不同時期科學家提出的問題與解決方法，或不同民族在生活中應用自然科學
SP01	科學的發現需要好奇心
SP02	科技的發明需要創意
SP03	應讓學生知道在具有扎實基礎的狀況下，獨立思考並判斷的重要性
SE01	科學可以便利生活，但也要遵守倫理、道德與法律的規範
SE02	應思考透過科學成就科技文明的原因與目的，以及科學真正的價值
SE03	應利用科學對社會與環境問題做出貢獻，以促進永續發展
SE05	以科學角度作為探討或解決社會議題的其中一種面向
SE06	科學的發展帶動經濟成長，使生活便利，但也可能造成貪心、浪費資源和汙染
SED01	科技是科學的展現，鼓勵學生利用科學知識解決生活中的各種問題
SED02	科學為了解決生活問題而開始思考，學校教育應給予學生適應未來生活的思考能力和探究空間
SED03	強調科學包括規律、模型和理論。透過科學的技術和應用可以解決社會問題
SED05	學生需具備科學知識和論述能力，才能有效的表達自己的想法。
SED07	學校應讓學生體驗科學的知識、應用和探究
SED08	科學知識應具有普遍性，並接受誤差的存在
SED09	中小學屬於基礎科學的建立，與實際的科學運作概念相同，但呈現方式不同
SED10	科學在生活中是許多器具的工作原理，可以讓學生體會科學的實用性
SED11	科學教育應該包含抽象的理論模型與實體的物品，讓學生將兩者連結起來

肆、 目前完成及預定完成之進度

時間 / 預計行事	113					114						
	8	9	10	11	12	1	2	3	4	5	6	7
~~【文獻探討】科學史與科學哲學脈絡~~	■	■										
~~【研究一】與科學博物館梳理科學史脈絡~~		■	■	■								
~~【研究二】科學史與科學哲學德懷術研究~~				■	■	■	■					
【研究三】教師專業社群發展課程							■		■			
【研究四】課程介入及學生學習成效評估									■	■	■	
資料分析與結果報告撰寫											■	■

後續進度規劃：

- 2025年3月：進行教師專業社群籌備工作
- 2025年4月：進行【研究三】教師專業社群之課程發展、審查及修正調整
- 2025年5-6月：進行【研究四】課程介入及學生學習成效評估
- 2025年7月：進行資料分析及結案之報告撰寫

伍、 討論與建議(含遭遇之困難與解決方法)

1. 科學本質之概念化相對困難，且面向多元。在進行文獻探討時資料來源眾多且複雜，因此本研究經過審視教師在第一份問卷中的回應之後，決定以科學哲學(PS)、科學史(HS)、科學知識社會學(SSK)、科學心理學(SP)、科學倫理學(SE)及科學教育(SED)等面向進行科學本質的概念化。
2. 德懷術研究過程較長且問卷填答較繁複，因此在招募參與者時需考量研究對象之流失問題，本研究以流失率80%做估計，最初招募約60人，最終完成問卷之人數為14人。
3. 科學教育計畫專案以中小學為場域，研究對象多為學生，理應申請人類研究倫理審查，然而在尋找委託審查單位時，卻被國立彰化師範大學之研究倫理審查委員會以計畫主持人非校內人員，且不接受非大學之單位委託審查為由拒絕。最終只得捨近求遠尋求國立臺灣師範大學之研究倫理審查委員會協助審查工作，以完備研究程序。

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