

以「樂齡科技」為主題的跨學科創科課程實踐研究 —— 香港中學 STEAM 教育的設計與實施案例

Implementation of an Interdisciplinary Innovation and Technology Curriculum with the Theme of "Gerontechnology": A Case Study of STEAM Education Design and Practice in a Hong Kong Secondary School

李偉傑

佛教何南金中學 創科課程小組

lwka@bhnkc.edu.hk

【摘要】 本文闡述的是以「樂齡科技」為主題的跨學科創科課程實踐案例。該課程旨在運用設計思維與跨學科學習策略，全面培育學生的創意思維、科技實踐應用能力及社會責任感。課程整合了科學科、電腦科及設計與科技科的知識體系，並實施了一系列多元化的教學活動，以支援學生從創意構想到產品原型展示的全過程。本文將詳細介紹課程的設計理念、跨學科協作模式及具體實施細節，並從教育意義與未來發展兩方面提出改進建議，為推動香港中學 STEAM 教育提供參考。

【關鍵字】 跨學科；創新科技；STEAM 教育；專題式學習；樂齡科技

***Abstract:** This article presents a case study of an interdisciplinary innovation and technology curriculum on "Gerontechnology," aimed at nurturing students' creativity, technological skills, and social responsibility through design thinking and interdisciplinary learning. It integrates knowledge from Science, Computer Literacy, and Design & Technology subjects, supported by diverse activities guiding students from ideation to prototype demonstration. The article discusses the curriculum's design principles, cross-curricular collaboration, and implementation while offering insights into its educational significance. Recommendations for future improvements are provided as a reference for advancing STEAM education in Hong Kong secondary schools.*

Keywords: Interdisciplinary, Innovation & Technology, STEAM Education, Project Based Learning, Gerontechnology

1. 前言

自香港特區政府於 2015 年發佈《推動 STEM 教育——發揮創意潛能》報告，明確提出以 STEM 教育作為未來教育改革的重點（香港教育局課程發展議會，2015），香港的 STEM 教育發展出了多元化的實踐形式。例如，許多中小學開設了 STEM 專題課程、舉辦校內或跨校科技創意比賽，並積極與大學、非政府組織及企業合作，利用社會資源為學生提供更廣闊的學習平台，讓其能夠參與實際的科技應用項目。近年來，學界更進一步將藝術（Art）加入科技教育，增添人文關懷與創意元素，形成了 STEAM 教育的完整框架。儘管 STEAM 教育在香港已取得一定程度的成效，但其發展過程中仍面臨諸多挑戰。首先，傳統以學科為導向的考試與評估體系，限制了 STEAM 教育的課程時間與深度。部分學校將 STEAM 課程安排為課外活動或非常規學科（如增潤課程），導致了學生在 STEAM 領域的學習體驗缺乏連貫性，

亦難以深入拓展。此外，跨學科整合的教學設計對教師的協作要求較高，而現有師資培訓體系尚未完全適應這一需求。因此，如何通過跨學科聯動的常規課程提升學生在 STEAM 學習中的積極性和參與度，成為了香港進一步推動 STEAM 教育的關鍵課題。

2. 課程設計

2.1. 設計目標

基於上述背景，本校設計並實施了一套跨學科的創科課程，在各科原有的常規課堂中，構建了一個以設計思維為核心的跨學科協作模式，引導學生開發創意解決方案以提高老年人的生活質素，通過創新的教學設計提升學生在 STEAM 學習中的學習成效，具體目標包括：

1. 提升學生的創意思維、科技與科學的應用能力：通過專題研習及多元的學習活動，幫助學生掌握 STEAM 學科中的核心技能，並激發其對創新科技及科研的興趣。

2. 增強學生的社會責任感與同理心：引導學生關注社會問題，理解科技在改善人類生活中的作用，從而樹立積極的價值觀與態度。

3. 促進跨學科學習與合作：整合科學、電腦、設計與科技學科知識，探索跨學科教學模式在實踐中的應用價值。

2.2. 課程計劃

主題：樂齡科技

對象：全校中三級學生

內容：學生以班內小組形式進行分組，每組由四名成員組成，設計並開發創新解決方案，以提升長者生活質量為目標。學生需結合跨學科領域知識與技能，並應用科技軟件及工具實現產品設計與開發。課程包含外出參觀、資料蒐集、創意發想、產品設計及成果展示等活動。

2.3. 樂齡科技主題的引入與重要性

文德榮和吳善揮（2022）認為若要加強學生的學習動機與學習的實用性，需探索 STEAM 與社會需求相結合的教學模式。樂齡科技作為一個新興領域，結合了科技創新與人口老齡化問題，為 STEAM 教育提供了重要的應用場景和學習主題。根據聯合國調查數據（2017），全球人口老齡化正在加速。2050 年，全球 60 歲及以上人口將達到 22 億，佔總人口的 20% 以上。香港作為全球老齡化程度最高的地區之一，65 歲及以上人口比例已由 2011 年的 13% 上升至 2021 年的 20%，並預計在 2036 年達到 33%（香港統計處，2021）。老齡化現象不但對香港的醫療及社會結構帶來挑戰，亦對科技創新延伸出了新的需求。

樂齡科技的核心在於利用先進科技（如人工智能、物聯網、機械人技術等），為長者提供智能化解決方案，以改善其生活質量並促進健康老齡化。這一領域不僅涵蓋科學、科技、工程、數學等多學科知識，還融入人文關懷與社會責任，為學生提供了豐富的跨學科學習機會。通過專題學習，學生能夠將課堂知識應用於真實問題，從而促進其創意思維與解決問題能力的提升（Chen et al., 2022）。

2.4. 跨學科協作模式

創科課程結合科學科、電腦科、設計與科技科（本校稱 STEAM 科）的常規課堂，通過專題式學習的形式讓學生完成從需求調研、產品設計到測試驗證的過程。

第一階段：科學科在課程中扮演著開拓者一角，為學生提供長者健康管理與生活需求的科學知識基礎，從中引導學生運用創意思維框架，將問題具體化並探索解決方案。

第二階段：電腦科負責教授學生運用微型處理器進行產品的技術實現，並結合多種感應器技術為產品賦予智能化功能，將編程知識轉化為具體的產品功能。

第三階段: STEAM 科強調將設計思維應用在創新產品開發中, 因此學生需學習使用 3D 建模工具完成產品的外觀設計與打印, 將創意轉化為實物。

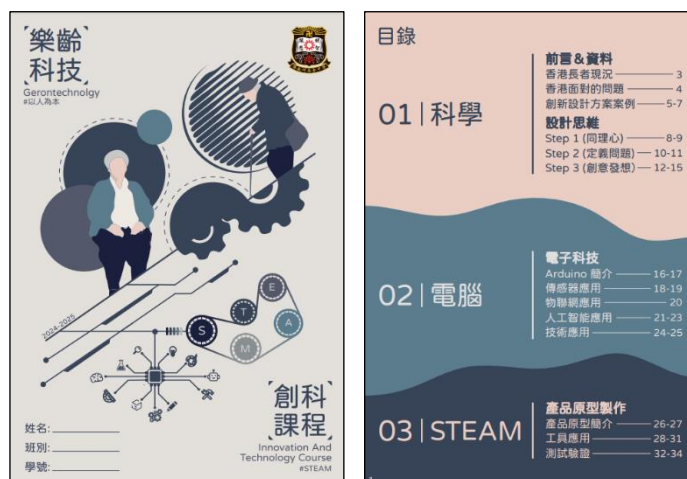


圖 1. 跨學科製作的課程手冊

2.5. 課程時序

創科課程以設計思維講座作為引入, 其後進行外出參觀及體驗活動, 讓學生透過實地觀察和交流, 了解現有的樂齡科技產品及服務, 並深入認識相關技術如何應用於改善長者的日常生活。其次, 學生將**隔週依時序於科學科、電腦科、STEAM 科的常規課程中開發創新解決方案**, 並展示產品對長者生活的實際影響及可能的社會價值作成果分享。而任教創科課程的科學科、電腦科及 STEAM 科教師亦會以指導老師的身份入組提供協助。

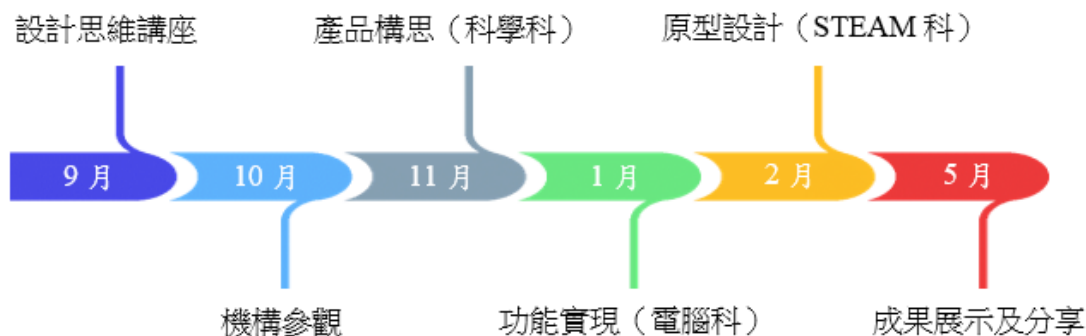


圖 2. 時間線

3. 課程實施細節

3.1. 設計思維講座

設計思維講座作為課程的開首, 旨在向學生介紹創科課程的進度安排、預期成果以及設計思維的重要性。通過產品設計及案例分享活動 (如 DJI 無人機和可口可樂品牌故事), 向學生展示通過設計思維所創造出的產品如何滿足用戶需求及引起使用者的情感共鳴。講座同時帶出樂齡科技主題的背景與需求, 分析香港邁入高齡化社會的背景, 指出長者在健康管理、行動便利及社交孤立等方面的挑戰, 以及樂齡科技在解決這些問題中的潛在作用, 鼓勵學生針對這些需求進行討論。講座結束後, 學生將理解設計思維的核心理念, 並對其在樂齡科技中的應用有基本的認識, 這為後續的機構參觀、創意發想及產品設計活動打下了基礎。



圖 3. 講座簡報內容節錄

3.2. 機構參觀

外出參觀是課程的重要環節，通過實地考察明愛賽馬會照顧者資源及支援中心，學生能夠直觀地了解到樂齡科技的應用場景及發展現狀。在參觀過程中，學生需分組進行多項互動體驗活動，例如：「輪椅過的士」體驗，通過模擬輪椅使用者在乘搭公共交通時的移動困難，啟發學生思考如何通過科技設計改善長者的行動便利性。活動不但讓學生了解現有樂齡科技產品的功能與設計邏輯，更重要的是通過實際體驗促進他們建立對長者需求的同理心。參觀結束後，學生將回到科學科課堂進行討論，整理活動中獲得的一手資料與體驗感受，為後續的創意發想提供素材。這些觀察和記錄將成為學生設計解決方案的基礎，有助幫助他們將知識與實際需求相結合，構思創新解決方案。



圖 4. 學生在機構進行照顧長者體驗活動

3.3. 產品構思（科學科）

科學科承擔著引導學生運用科學知識進行產品構思的核心角色，幫助學生從長者的實際需求出發，結合科技，提出創新且可行的初步想法。教學活動主要使用了三種框架幫助學生把科學理論轉化為創新產品概念。

1) 同理心地圖：學生以小組形式進行長者需求分析，透過案例研究、數據分析及模擬情境（如視障、聽障及行動不便），深入體驗長者所面臨的生活挑戰。

2) 5W1H 分析框架：在同理心階段收集的洞察基礎上，學生運用 5W1H 框架具體化問題，明確產品設計的目標與方向，例如以下具體活動：

Who: 確定目標使用者（如行動不便的長者或需健康監測的長者）；

What: 分析長者需要解決的核心問題（如健康提醒、行動輔助或社交增強）；

When: 定義產品的使用場景和頻率（如日常生活、醫療檢查或緊急情況）；

Where: 確定產品的使用場所（如家中、戶外或醫療機構）。

Why: 探討問題的根本原因及改善的價值；

How: 初步構思產品的實現方式和技術方向（如利用感應器、AI 或物聯網技術）。

3) HMW (How Might We) 框架：學生以腦力激盪的方式，運用「HMW 我們如何...」工具將問題轉化為創新產品概念，提出多樣化的解決方案。例如：「我們如何設計一款能實時監測健康數據的可穿戴設備？我們如何幫助行動不便的長者更輕鬆地完成日常出行？」。

學生需要把創意發想的方案繪製草圖，記錄在創科冊子中，以便進一步改善設計。

3.4. 功能實現（電腦科）

學生帶着在科學科完成的產品初稿進入電腦科學習階段，進一步將概念設計轉化為具體的功能。在教授了基本的處理器及感應器課題後（Arduino Uno 開發板 及 超聲波感應器、光敏電阻等），電腦科老師會根據學生的產品設計需求，推薦合適的感應器和處理器，如：健康監測設備、心率感應器、溫度感應器等。以製作智能導航輪椅為例：學生需選擇超聲波感應器進行距離測量，並搭配 Esp32 開發板進行無線控制。此階段學生將以分組協助形式進行課堂，通過編程實現至少一項產品功能，並結合原型進行測試與優化。學生通過實作練習，更深入了解新興技術，如物聯網、人工智能等概念。而科任老師會適時為學生提供技術支援，解答硬件連接與程式設計中的疑問。

3.5. 原型設計（STEAM 科）

在 STEAM 科的課程中，學生需把他們的創意和功能性設計轉化為實體的產品原型。學生將學習使用 3D 建模軟件（Fusion 360）設計產品的外觀和結構。教師則會通過示範教學，指導學生將他們的創意轉化為電子化模型。在設計過程中，學生需要考慮產品的實用性、美觀性和人體工程學，確保設計不僅符合功能需求，還能夠為長者提供舒適的使用體驗。完成 3D 建模後，學生將使用 3D 打印機或紙皮等環保物料，將設計轉化為實體模型。教師會向學生介紹不同類型的材料及其特性，幫助學生根據產品功能運用合適的材料。此外，學生還會學習優化打印參數（如層高、填充）以提高打印質量和效率。在原型製作過程中，學生需要與科學科和電腦科的任教教師保持密切溝通，確保原型的設計與技術實現能夠無縫銜接。例如，學生可能需要調整產品的尺寸以適應電腦科開發的電子元件，或者根據科學科的需求分析優化產品的使用場景。通過不斷的測試和反饋，學生能夠對原型進行疊代改進，逐步完善他們的設計。

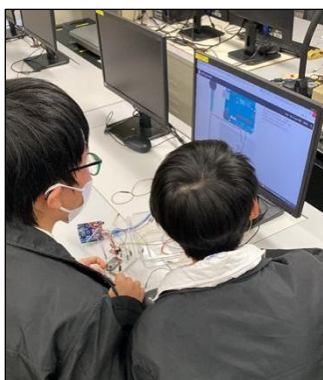
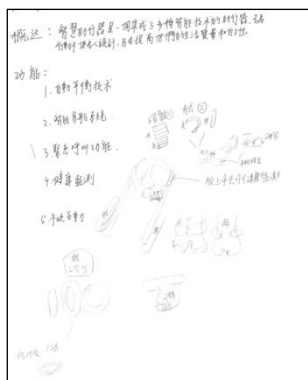


圖 5. 產品構思（科學科）圖 6. 功能實現（電腦科）圖 7. 原型設計（STEAM 科）

3.6. 成果展示及分享

在課程的最後階段，學生將參與全校性的成果展示活動：在午息或放學時段以攤位形式向全校師生展示作品。展示活動能夠幫助學生更好地反思他們的學習過程，識別其中的優點和不足，從而為未來的改進提供方向（Kolodner et al., 2003）。每個小組會設計展板，詳細介紹他們的產品理念、功能特點以及解決的實際問題。展板內容包括產品設計草圖、3D 模型圖、功能演示等，更直觀地向觀眾傳達他們的設計思路。當學生清晰地向觀眾介紹他們的

設計理念，有助提升他們的表達能力和溝通技巧（Hmelo-Silver, 2004）。同時，科學科、電腦科和 STEAM 科的科任老師會就各組設計的產品進行模擬場景和問答環節，例如長者在使用智能導航輪椅時，遇到斜坡或樓梯時，智能輪椅是否能保障長者的安全？是否能提早感應並跟換更佳的導航路線？在答辯的環節中，學生需要思考產品如何解決將面臨的實質性難題，以及如何優化他們的產品。同時，也能讓他們認識到該產品設計對受眾者和社會的影響，從而增強他們的社會責任感（Barron & Darling-Hammond, 2008）。最後，各科任老師將綜合學生的展板設計、產品功能演示以及解決問題的能力進行評分。

評分機制能夠增強學生的學習動機，幫助學生設定明確的學習目標，激勵他們不斷追求更高的成就（Hattie & Timperley, 2007）。評分標準包括創意性、技術實現、實用性、展示效果等。除了老師的評分，學生之間也會進行互評。每個小組將有機會參觀其他小組的展位，並根據他們的展示內容進行評分。這種互評機制不僅能夠促進學生之間的交流，還能幫助他們從他人的作品中獲得靈感。

展示活動結束後，學生將在課堂上進行反思與總結。他們需要分析展示過程中遇到的問題，並根據反饋提出改進方案。這一過程能夠加強鞏固他們的設計思維和解難能力。

4. 教學以外的工作

4.1. 創科小組會議與支援工作

創科小組的負責老師每隔兩周召開一次會議，主要目的是協調各科的教學進度，確保課程內容的連貫性和一致性。而其他支援工作內容包括：1) 三科匯報教學進度：科學科、電腦科和 STEAM 科的老師分別匯報各自的教學進度，分享教學中的成功經驗和遇到的挑戰。2) 調整進度表：根據教學進度和學生的反饋，調整課程進度表，確保每個階段的任務能夠按時完成。3) 活動籌備：籌備及協調與課程相關的活動，如外出參觀、講座、比賽和活動展示周。4) 教學材料採購：購買與課程相關的教學材料，如感應器、電子元件、產品設計原料等，並確保教學物資的合理分配和使用，避免資源浪費。

4.2. 教學材料設計與共同備課

為了確保課程內容的質量和一致性，創科小組的老師會共同設計和準備教學材料。具體工作包括：1) 教學材料設計：根據課程目標和學生的需求，設計適合的教學材料，包括課件、實驗指導工作紙、設計思維工具冊子等。2) 共同備課：科學科、電腦科和 STEAM 科的老師共同備課，確保各科的教學內容能夠相互銜接，形成一個完整的課程體系。3) 指導老師協調：協調小組指導老師注意課程中的關鍵環節，例如主要角色及工作（協助學生完善作品「意念」、監督學生進度、小組匯報練習等，技術支援則讓學生找電腦科及 STEAM 科任教老師）。

4.3. 課後支援與拔尖比賽

提供適切的課後支援及校外拔尖比賽能夠補充課堂內的教學內容，為學生提供了更多挑戰與發揮潛能的平台：1) 課後支援：定期開放創科中心、電腦室供學生在課後時間進行產品研發，並安排老師輪流當值，為學生提供技術指導與問題解答。2) 拔尖比賽：學校會通過評分機制和指導老師的觀察，挑選有潛力的組別參加校外比賽，以增強學生的自信心和競爭力，學生得以進一步鞏固所學知識，進一步激發他們的設計思維能力及擴闊視野。

5. 挑戰與改進

5.1. 教師協作與技術支援

挑戰：由於創科課程是一個全新的課程，學生的設計和構思亦千變萬化，教師需要不斷學習新的技術來支持學生的項目。如何合理安排任教教師的時間，確保兼顧教學和課程支持工

作是一個重要議題。課程中教師需要根據學生的想法，短時間內配對及掌握相關工具和技術，對教師的學習及應變能力提出了更高的要求。而教師在完成日常教學任務的同時，還需要投入大量時間學習新技術和提供課後支援，時間管理亦成為一大難題。

改進：通過跨學科協作，科學科、電腦科和 STEAM 科的教師需合理分工，各自負責擅長的領域，減輕個別教師的壓力。學校亦可組建有教學助理支持的團隊，專門負責解決學生在技術實現過程中遇到的問題，減輕教師的負擔。

5.2. 資源分配

挑戰：產品設計原材料、3D 打印機、感應器等設備的數量有限，學校需合理分配這些資源，確保每個學生都能獲得足夠的支持。外出參觀、講座、校外比賽需要一定的資金支持，無疑考驗着學校的資源調配政策。同時，由於課程面向全級學生，學生的學習差異和項目需求差異的鴻溝跨度較大，如何為有需要幫助的學生提供基礎協助，同時為拔尖學生提供更高難度的挑戰，亦是個難以平衡的問題。

改進：學校或可能需與外界機構（如政府機構、大學）合作，善於共享設備和資源優勢，為學生提供更多的支持。同時，對於科組內可分配資源的審核亦需更嚴謹，以減少不必要的支出。教學方面，根據學生的技術水平和項目需求，學校可以實施分層教學。對於基礎較弱的學生，提供更多的技術指導和基礎協助，甚或可建基於已有的解決方案作改良；而對於拔尖學生，則可設定更高的標準，並鼓勵他們構想更創新的項目。

5.3. 評估與反饋的有效性

挑戰：由於創科課程涉及多個學科，評估標準需要涵蓋創意性、不同學科知識、團隊合作、社會責任感等多個方面。如何制定一個全面且公平的評估標準，確保每個學生的表現都能得到客觀的評價是一個挑戰。由於課程橫跨不同學科，反饋機制同時考驗學生的自我評估能力，部分學生難以準確認識自己的優點和不足，或過於被動向教師諮詢，從而影響他們的學習效果。

改進：創科小組需要重視各學科的意見，集合多元化的評估標準，涵蓋創意性、技術實現、團隊合作、社會責任感等多個方面。通過明確的評估標準，確保學生在每個階段的任務完成後都能獲得教師的反饋，幫助他們調整設計和學習策略。另外，各科可加入反思及互評環節，幫助學生從他人的角度了解自己的表現，進一步提升他們的自我評估能力。

6. 結語與展望

本文探討了以「樂齡科技」為主題的跨學科創科課程設計與實施案例，展示了本校如何透過 STEAM 教育應對人口老齡化問題的教育創新實踐。課程實施期間，科任老師觀察到學生展現出較傳統學習更高的學習主動性。在電腦科及 STEAM 科的專題學習中，約一半小組學生主動利用課餘時間研究進階編程技術或 3D 建模技巧，展現出對創新科技與科研的興趣。透過設計針對老年人生活質素的創新解決方案，學生能將課堂知識與實際社會問題相結合，並在成果展示中提升其科學思維與表達能力，亦展現了對社會問題的關注，與課程設計理念契合。此外，加入課後支援與拔尖比賽環節，照顧了學生的多樣性，除了推動了普及科技創新教育，亦提供更多挑戰高難度課題的機會，刺激學生的潛能發展。然而，這一課程的實踐確實面臨著不少挑戰，包括教師協作與技術支援的壓力、資源分配的有效性，以及跨學科評估機制的完善性。這些問題的解決需要學校層面更高效的資源管理與政策支持，以及教師層面的專業發展並提升協作能力。相信未來隨着教育政策的進一步推進及學校資源的優化，香港的 STEAM 教育將能更好地發揮其在培養創新人才及促進社會進步中的關鍵作用。而本主

題的未來研究將進一步採用量化分析方法，以更全面和客觀地評估學生的學習成果，為後續課程的優化提供數據支持，從而持續改善創科教育的設計與實施。

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Integrating Frontier Technologies through Project-Based Learning and Productive Failure: Cultivating Innovative Learners in Chinese Education

Hok Sing Stanley, Tsui

Faculty of Education, The Chinese University of Hong Kong, Hong Kong SAR, China

kei-hst@cccmkc.edu.hk

Abstract: Education in Chinese has traditionally stressed memory and mastery by repetition, a passive learning approach progressively incompatible with the demands of the knowledge economy of the 21st century. Combining frontier technologies like Artificial Intelligence (AI) and Machine Learning (ML) into Project-Based Learning (PjBL) and Productive Failure (PF) approaches has transforming power for producing creative students. This paper reviews significant research like Chen and Yang's (2019) review of Project-Based Learning, Kapur's (2008) studies on PF, and Chi and Wylie's (2014) ICAP framework—to carefully consider what these signify for learning with technology in Chinese educational contest. This paper offers theoretical explanation and practical advice for teachers looking for innovation in the classroom by precisely defining and contextualizing PF inside the Chinese educational scene and making explicit links to innovative technology applications.

Keywords: Artificial Intelligence (AI), Chinese Education, ICAP Framework, Productive Failure (PF), Project-Based Learning (PjBL)

1. Introduction: The Need for Technological and Pedagogical Integration in Chinese

Education

Learning is a transforming process built on prior knowledge. The National Research Council (2000) claims that rather than starting from zero, students leverage their past knowledge, experiences, and beliefs for new learning possibilities. Like a sturdy foundation is needed while building a structure, new information is constructed on an existing knowledge. Ignoring these fundamental elements would lead to misconceptions, much as a structure would fall without a strong basis.

Characterized by memorization and passive knowledge absorption, traditional Chinese education comes under more criticism in our fast changing, technologically driven culture (Rao, Chi & Cheng, 2010). Learner autonomy, critical thinking, and adaptability—skills extensively developed by creative pedagogies such Project-Based Learning (PjBL) and Productive Failure (PF)—emphasize current worldwide educational trends. These pedagogies combined with frontier technologies (AI & ML) have the potential to turn students into creative problem-solvers, therefore complementing the conference subject.

2. Theoretical Background: Productive Failure and Project-Based Learning

It is not news that Hong Kong is undergoing constant technological transformation. It presents special challenges for the educational system in Hong Kong. While most children have access to electronic devices both inside and outside of the classroom, the way smart devices are used to foster critical thinking and problem-solving ability is more important than their availability. Teachers have to use Technological Pedagogical Content Knowledge (TPACK) framework (Tseng et al., 2022), which gets pupils ready for the interaction of modern life in an AI-driven world. Growing these skills calls for the application of methodologies including Project-Based Learning (PjBL) and the ICAP framework.

Comprehensive teacher development initiatives are absolutely necessary if PjBL is to fully realize in Chinese classrooms. To properly combine new technology with solid subject content knowledge, educators must be conversed in the TPACK framework, therefore guaranteeing a seamless and efficient change toward innovative pedagogies. Establishing professional learning communities and mentoring programs inside educational institutions helps to enable constant innovation and peer-exchange of best practices. These kinds of communities help teachers not only during the change from conventional approaches but also promote a cooperative culture of continuous professional growth.

2.1. Productive Failure (PF): Foundations and Benefits

Clearly stated by Kapur (2008), Productive Failure (PF) is pupils first trying to tackle difficult, unsolved creative problems with ambiguous direction, then guided by structured training. Based on empirical research by Kapur (2008), PF greatly improves conceptual understanding and transfer capacity without sacrificing procedural fluency. This is consistent with studies in cognitive science (National Research Council, 2000), which emphasizes on learning by struggle as a necessary road towards great insight.

Recent studies show that the PF theory improves many facets of learning, including students' learning attitudes, learning interest, self-efficacy, creativity, cognitive load management, group collaboration skills, deep learning capacities, problem-solving ability, and computational thinking (Creely et al., 2024). Still, several researchers have voiced reservations. Hung, Chen & Lim (2009), for instance, have questioned its impact on habit formation by contending that both methods should finally converge within a dialectical learning process regardless of whether a learner starts with known theoretical knowledge or personal experience. Regarding procedural knowledge—like learning to bowl—he argues further that the evolution of “bad habits” during autonomous practice is nearly certain.

Moreover, it gets more difficult to unlearn or change these patterns the more autonomy is promoted. We are exploring, in the framework of successful failure, the latent advantages of education. Scholar Cao et al. (2020) have also contended that the PF theory suggests that it would not be appropriate for elementary school pupils since it assumes a certain degree of metacognitive capacity and prior knowledge. Using cooperative learning based on the PF theory in fourth- and fifth-grade classrooms might also function just as well as, or even worse than, learning alone. According to Mazziotti et al. (2019), since younger pupils have limited metacognitive skills and drive to learn. These issues draw attention to the need of greater research to ascertain how far the theory may be used, to modify teaching strategies to match various student needs, and to ensure that the failure process does not produce bad or negative learning outcomes.

2.2. Project-Based Learning (PjBL): A Constructivist Approach

PjBL, according to Krajcik and Shin (2014), is an inquiry-driven learning tool whereby students actively explore and technologically integrate significant real-world problems, therefore acquiring more practical knowledge on problem-solving on authentic settings. The evaluation of studies by Chen and Yang (2019) suggests that PjBL is effective and that routinely using technology—such as digital presentations and interactive software—helps to improve learning outcomes in STEM and social science disciplines. Apart from the course of instruction, PjBL promotes essential soft skills including leadership, interpersonal cooperation, and good communication. In a world growing more linked by technology and where success depends on these abilities, they are absolutely essential. These will also be a differentiator in a Chinese education rivalry.

Projects leveraging China's rich cultural legacy, history, and social ideals can be included into PjBL to reflect those values. Teachers can assist students realize the importance of modern scientific and technical concepts in context by organizing inquiry-based projects around local issues or traditional themes, therefore raising their engagement and motivation. Although conventional Chinese education has historically stressed rote memory and mastery, including PjBL offers a balanced approach—keeping fundamental knowledge intact while turning toward more learner-centered techniques. This slow change enables the balancing of the demand for innovation with respect for accepted educational methods.

3. Relevance of PjBL and PF in Chinese Education

Creative pedagogies, which promote critical thinking and problem-solving abilities necessary for 21st century competencies (Lee, 2018), have become even more important under Chinese educational reforms (Rao, Chi & Cheng, 2010). Though cultural preferences for regimented, teacher-centric classrooms abound, recent legislative changes toward student-centered pedagogies expose openness to approaches such as PjBL and PF. Examining metropolitan and rural classrooms in China reveals that by properly training and running classrooms, one may effectively incorporate these teaching strategies in local environments, therefore overcoming traditional obstacles.

3.1. *Chen and Yang's (2019) Meta-Analysis on Project-Based Learning*

Chen and Yang set out to investigate how PjBL changed student performance. Examining studies done between 2000 and 2017, they sought to find whether PjBL had been more effective over time compared to conventional training. They also aimed to ascertain the factors influencing PjBL's effectiveness: subject matter, instructional length, class size, and technology support.

3.2. *Chi and Wylie's (2014) Study on the ICAP Framework*

Chi and Wylie created the ICAP paradigm by grouping cognitive activity into four categories: Interactive, Constructive, Active, and Passive. Their major objective was to provide educators with a practical structure for assessing and raising student involvement. By applying the framework, which specifies several modes depending on observable actions, teachers can design activities promoting deeper cognitive processing.

4. Methodologies

They have published an extensive study of quantitative research contrasting academic achievement in PjBL settings with conventional instruction. Peer-reviewed papers offering sufficient statistical data were part of the study. They estimated effect sizes with Hedges' *g* and performed moderator studies to identify the factors affecting PjBL's efficacy. Additionally, they looked at the body of studies on learning outcomes and student involvement to develop the ICAP structure. They examined the data linking each of the four engagement modes to relevant learning objectives following their classification of learning activities into those four modes. This validation showed that learning gains steadily move from passive to interactive forms.

5. Results

5.1. *Findings from Chen and Yang's (2019) Meta-Analysis*

Chen and Yang's meta-analysis suggests that one of the most interesting results should be "PjBL can improve academic performance." The study shows PjBL has a notable overall effect size of 0.71, therefore benefiting the academic performance of the students. With an amazing impact size of 1.05, the domain "Social Sciences" is the most effective one. Science, Mathematics, Technology, and Engineering (STEAM) came next, suggesting PjBL is rather helpful in these fields. Moreover, the study underlines the need of instructional frequency since academic results show that PjBL used for more than two hours every week improves. Another important successful criterion is technology infusion since using education technologies such as interactive slideshow data presentation and spreadsheet data analysis increases the efficacy of PjBL, particularly for the process of research and presenting before their classrooms.

Remarkably, PjBL's benefits are consistent across educational levels—from Grade 5 to college—that shows its adaptability. The studies also show geographical variations, with larger effects shown in Europe, North America, and Western Asia compared to East Asia, suggesting that cultural influences may affect PjBL results.

5.2. *Findings from Chi and Wylie's (2014) Study*

The need of interactivity in learning activities is underlined by this study. The study emphasizes that passive participation—that is, learning outcomes from reading or listening exercises with little involvement—allows double the work for half the outcome. Active participation—that is, little changes in text underlining—has some advantages. More importantly, students gain greatly from constructive engagement—that is, from a new knowledge encoding by summarizing or expanding on subjects in their own.

Nonetheless, the study reveals that “a stitch in time” results from interactive participation, which is my ideal approach incorporating group projects allowing students to co-construct knowledge by means of constant feedback and discussion. This study reveals that increasing educational results depends on designing an interesting learning environment. Therefore, both studies underline the need of participation and the strategic application of instructional strategies like PjBL to raise academic performance in different conditions.

6. Frontier Technologies Matters: AI and ML in PjBL and PF

Not only does including Artificial Intelligence (AI) and Machine Learning (ML) technology into PjBL and PF systems increase their relevance but also changes basic teaching methodologies. AI-driven intelligent tutoring solutions, for instance, can constantly assess student interactions and performance data and dynamically provide scaffolding to instantly clear misunderstandings, which reduce the risk of “bad habit” cultivation or even negatively impacting their self-esteem on solution exploring. These kinds of systems might examine how students understand “Tang poetry”(唐詩) or traditional Chinese literature in a Chinese language lesson, then offer tailored comments that enable students investigate further textual meanings and literary strategies. This process transforms first interpretative “failures” into chances for more thorough debate and critical analysis.

In science and math lessons—which are vitally essential in Mainland China and Hong Kong—AI can help to simplify difficult problem-solving techniques. An intelligent system might identify common mistakes and recommend focused mini-tutorials when students participate in PF activities on demanding subjects like algebraic or physics-based experiment. For a PF activity in a Hong Kong classroom, for example, pupils can be given an open-ended real-world problem with no clear answer right away. After then, the AI system might give clues, support constant learning, and finally direct pupils toward more advanced conceptual comprehension.

Furthermore, considerably improving project-based scenarios are predictive analytics and ML-powered simulations. Based on real-time student progress, students in Chinese history or civic education courses could use simulation technologies that modify the difficulty of tasks—such as replicating from historical Silk Road to One-Belt-One-Road or urban planning issues applicable to Hong Kong’s highly populated surroundings. Like real-world decision-makers, these simulations let students test theories regarding social, environmental, or economic challenges, iteratively honing their approaches. Supported by data analytics, this reinforcement loop deepens cognitive involvement in line with the ICAP paradigm.

Moreover, AI applications in Natural Language Processing (NLP) can automatically spot trends, learning gaps, and new ideas by analyzing classroom conversations and written comments on Chinese cultural content or modern challenges. NLP tools may, for instance, assess written proposals in a project where students examine how ancient Chinese values mix with modern technology and indicate areas that might call for more investigation. Whether in rural schools where flexibility is essential or urban areas like Hong Kong, where resources are plentiful, such instantaneous, customized feedback helps teachers to change project designs and teaching strategies on demand interactively.

Ideally, this adaptive and data-driven method redefines education by realizing that, rather than a setback, controllable failure is a necessary stage in the learning process. Teachers build a classroom that is always changing depending on real-time findings by including AI with ML into PjBL and PF. Along with encouraging remarkable participation and critical

thinking skill (慎思明辨) (Education Bureau, 2024), this gives students the creative, self-regulated learning platforms they need to meet the difficult, technologically driven problems of the 21st century (Lee, 2018).

7. Implementation Strategy: The ICAP Framework as an Integration Model with PjBL and

PF

With its classification of cognitive engagement into Interactive, Constructive, Active, and Passive modes, the ICAP framework (Chi & Wylie, 2014) offers teachers a disciplined road map for including frontier technologies into PjBL and PF systems. Teachers may greatly improve students' thinking skills by supporting interactive and constructive activities—such as group coding projects, AI-based peer feedback, and ML-driven data analysis—by employing AI and ML to support interactive and constructive activities—that is, by means of which higher learning outcomes arise.

7.1. Evaluation of Chen and Yang's (2019) Meta-Analysis

The meta-analysis by Chen and Yang thoroughly examines how PjBL affects academic achievement. Examining 46 effect estimates from 30 published papers—data from 12,525 students from 9 countries—using acknowledged statistical techniques including Hedges' *g*, Like a careful tailor guarantees a great fit, this large dataset and rigorous approach increase the credibility of the research. Investigating the several factors—mostly topic area, teaching time, class size, and technology support—that affect PjBL's efficacy, this meta-analysis This all-encompassing approach provides thorough insights, just as governmental urban designers consider several factors while creating first-rate infrastructure.

The study points up a few likely negatives. One unavoidable problem is “Publication Bias” (Stanley, 2005), which would cause PjBL's efficacy to be overestimated since it would overlook unpublished trials with non-significant results. Similarly, differences in techniques and evaluation tools cause variances in study quality, therefore limiting the extent of application of the results. These components imply that careful interpretation is required even with the positive findings.

7.2. Evaluation of Chi and Wylie's (2014) Empirical Study

Chi and Wylie's ICAP model breaks cognitive involvement into four categories based on observable actions. Based on cognitive science, this rigorous classification increases theoretical validity, much as “Feng Shui” arranges environmental elements for harmony. Research done in labs and classrooms yields empirical facts supporting the strategy. It provides teachers with a practical tool to design activities promoting near-transferred learning by linking engagement modes to learning objectives, much as a chef perfecting a dish to get the optimal balance of tastes.

The study acknowledges some limits that would affect its results. One major disadvantage of the range of settings the research looked at is this modification might restrict the applicability of the framework in educational environments. Moreover, direct experimental evidence is still necessary even if earlier studies corroborate the theory. Through such tests, the empirical basis of the framework would be reinforced, so providing greater evidence of its effectiveness. Therefore, even if the results are valuable, these shortcomings highlight the need of future research to confirm the generalizability of the framework in several environments and to deepen its theoretical foundations.

8. Addressing Cultural and Contextual Challenges

Integrating PjBL and PF effectively in Chinese education calls for careful thought on cultural attitudes on cooperation and failure. Chinese students' typical aversion of failing can be turned into a positive experience with well-organized PF events using AI to provide immediate, encouraging feedback free of judgment, therefore reducing their anxiety and hence to limit the shortcoming effect of PF. Likewise, culturally relevant instruction in collaborative dynamics and technology-mediated group management can help to solve problems in large-sized Chinese classrooms (Rao et al., 2010). The natural focus on cooperative projects in PjBL fits very nicely the collectivist cultural standards followed in Chinese society. By

encouraging students to work together, share ideas, and build on one another's skills, cooperative projects help to create an inquiry community that reflects both conventional group-based initiatives and contemporary collaboration methods.

Both research underline the need of learner involvement, which fits Kapur's idea of PF. Many times, kids learn by practical experience; early "intentional" challenges help pupils to actively build information and face difficult difficulties, therefore fostering deeper understanding. Chen and Yang's findings support the PjBL principles established by Krajcik and Shin (2014), stressing the need of well considered initiatives centered on significant issues. Both stress the need of professional development and strategic support and admit the challenges in implementing PjBL. PjBL guides students toward a development mindset by redefining failure as a necessary component of their education. These strategies are especially important in situations when a high-stakes exam culture and intolerance to mistake have always predominated. Using PF inside PjBL environments helps students to see challenges as chances for development and education.

Complementing active learning approaches, the ICAP framework is a useful instrument for evaluating and raising cognitive involvement. It helps to shift from teacher-centered to student-centered learning and emphasizes critical thinking and cooperation—two soft skills that are absolutely vital in modern education. These studies greatly progress educational research by providing useful insights and improving our knowledge of effective teaching strategies. While Chen and Yang offer empirical data regarding the success of PjBL, Chi and Wylie offer a beneficial paradigm for increasing student involvement. With careful literature evaluations and well-expressed methodologies and findings, the study is also quite accurate and exhaustive. By owning their flaws and delineating possible paths of research, they show intellectual honesty and rigidity. Furthermore, both pieces are logically organized to guide readers through their arguments. By means of relevant examples and actual facts, their persuasive power is effectively raised, thereby enabling researchers and teachers equally to grasp challenging concepts.

9. Reactions

9.1. *Professional Reflections and Practical Recommendations*

When considering personal experiences using PjBL with ICT projects and including artificial intelligence technology, student involvement and learning results have much improved. Using AI-based coding tools, for example, improved students' productive struggle and teamwork; ML-driven analytics gave exact understanding of their approaches of problem-solving. Such methods show concrete, contextually relevant ideas consistent with the conference theme.

The readings stress the need of cognitive engagement in the course of education. As a teacher, I have seen firsthand how directly student involvement affects their learning efficacy, speed, quality, and retention. PjBL and the idea of PF really fit my teaching background. Including PjBL exams into my classes all through the academic year helps students to engage directly with their peers. This approach creates a cooperative atmosphere where knowledge generation takes place. Even if their early contributions could be meager, the interactive process improves their aptitude for collective problem-solving and enhances their social abilities. This proves the power of cooperation and is in line with the Chinese proverb, "Three humble shoemakers make a great strategist." (三個臭皮匠，勝過一個諸葛亮。)

Giving kids the ability to conquer challenges away from direct oversight fosters perseverance and critical thinking. I assign long-term group projects with flexible rules to students, for instance, so they may explore, make assumptions, and learn from their failures. By providing little dosages of advise based on their growth, I build resilience and repeat that failure is a vital step on the road to success.

9.2. *Questions Raised*

Future studies should empirically investigate the particular ways in which artificial intelligence and machine learning could improve PF in Chinese classrooms, looking at longitudinal effects on learner attitudes regarding failure, persistence, and cognitive engagement. More study could provide ICAP-based teaching strategies catered to Chinese culture and test their performance in various Chinese educational settings. When combined with modern technologies, PjBL becomes a