教育部教學實踐研究計畫成果報告

Project Report for MOE Teaching Practice Research Program

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開放式課程「工程數學」之重點以動畫方式加以呈現的探討

[配合課程名稱：工程數學(一)、工程數學(二)]

計畫主持人(Principal Investigator)：呂志宗

執行機構及系所(Institution/Department/Program)：中華大學／土木工程學系

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摘要

本計畫是以白板動畫的方式，呈現 100 個以上之工程數學的重要觀念，用以加深同學們學習工程數學時的印象，並以開放式課程的形式，分享至 YouTube 的開放式課程平台上，用以幫助網路上對工程數學的學習有興趣之莘莘學子們。相關之動畫的製作，是以白板動畫為主軸，再搭配其他適合的影音編輯軟體，進行動畫的製作。

本課程所採用的教學方法是以問答教學法、資訊科技融入教學法、和自學輔導法等為主，並採用問卷調查法、前後測和質性分析方法評估教學成效。本計畫之研究成果已發表兩篇國際期刊論文，研究成果有助於：(1)將工程數學的關鍵重點多媒體化。(2)創造出自主學習的教學環境。(3)提供觸類旁通的學習機會。(4)建構單元主題式之學習教材。(5)建置行動學習的環境。

由李克特五等尺度量表之問卷分析結果得知，問卷分數達 4.69 分，亦即同學們的學習回饋之平均成績是屬於「非常好」的等級。此外，本計畫引用 Moodle 平台之線上測驗功能，分別安排工程數學(一)和工程數學(二)進行 10 次與 12 次的知識點小測驗之前測與後測。其中工程數學(一)之前後測成績分別為 48.61 分與 92.39 分，工程數學(二)之前後測成績分別為 47.77 分與 90.33 分。以上努力顯示，本計畫所完成的動畫，極有助於提升工程數學之學習成效。

關鍵字：工程數學、開放式課程、白板動畫、科技融入教學法、自學輔導法

ABSTRACT

This project aims to present over 100 important concepts in engineering mathematics using whiteboard animation. The goal is to deepen students' understanding of engineering mathematics and share the content on YouTube's open course platform as an open course. This can help aspiring learners who are interested in the virtual study of engineering mathematics. The animations are created primarily through whiteboard animation techniques, combined with other suitable video editing software.

The teaching methods employed in this course include inquiry-based learning, integration of information technology into teaching, and self-guided tutoring. The effectiveness of the teaching is evaluated through questionnaire surveys, pre-tests, post-tests and qualitative analysis methods. The research outcomes of this project have been published in two international journal papers. The research findings have contributed to (1) using multimedia to represent key concepts in engineering mathematics, (2) creating a self-directed learning environment, (3) providing opportunities for analogical reasoning, (4) constructing unit-themed learning materials, and (5) establishing a mobile learning environment.

The questionnaire was created on a Likert 5-point scale, and the student's satisfaction with teaching videos is scored at 4.69 on average. Additionally, this project utilizes the online quiz functionality of the Moodle platform to conduct pre-tests and post-tests for 10 sessions in Engineering Mathematics I and 12 sessions in Engineering Mathematics II. The pre-test and post-test scores for Engineering Mathematics I are 48.61 and 92.39, respectively. For Engineering Mathematics II, the pre-test and post-test scores are 47.77 and 90.33, respectively. Most students favored the quality of the engineering mathematics materials in the educational videos. Besides, animation added to this project significantly enhanced the learning effectiveness of engineering mathematics.

Keywords: Engineering Mathematics, OpenCourseWare, Whiteboard Animation, Information Technology Integrated into Instruction, Self-study Tutoring

目錄

開放式課程「工程數學」之重點以動畫方式加以呈現的探討

一、研究動機與目的(Research Motive and Purpose)

主持人已在本計畫中完成 200 多個工程數學動畫，並以教材清單的方式，安置於 YouTube 平台，每個動畫之說明欄中，均提供與動畫主題相關之超連結，學習者可以透過超連結，下載教材、瀏覽板書解答、檢測自學成效、學會符號運算解題方法、進行關聯影片的學習等，這些連結多是整合近 5 年來，教育部補助計畫主持人所完成的工程數學之教學研究成果。

本計畫之研究動機包括以下幾點：

- **將工程數學概念視覺化並趣味化**：工程數學概念對許多學生來說是相當抽象和難以理解的，透過所製作之視覺化和趣味化的動畫，可以幫助學生更容易理解工程數學中之複雜觀念。
- **增強教學效果**：動畫可以使教學更具吸引力和互動性，有助於提高學生的參與度和學習效果，這對於培養工程領域的專業能力尤其重要。
- **克服語言障礙**：工程數學動畫中常會引用特定的專業術語和運算符號，此有助於跨越語言的障礙，使工程數學內容更容易理解，特別是在當今國際化的學習環境中，更有其需要。基於此，計畫主持人在動畫中之文字描述，是以中英文並列的方式，進行各項解說。
- **提高學習動機**：精心設計的動畫可以激發學生們的興趣，提高他們的學習動機，因為動畫可以提供有趣且具體的學習體驗。

計畫主持人是採用數位科技融入教學的模式，進行同步的實體課程授課，及非同步的開放式課程之授課，祈望透過製作動畫教材的教學設計，吸引同學們持續建立自主學習的習慣。本計畫之研究目的有以下幾項：

- **建立自主學習的習慣**：自主學習的習慣極有助於個人成長和職涯發展，以動畫呈現的工程數學教材，可以讓學生們更樂意親近工程數學，因為即使學生們一開始對工程數學毫無興趣，但亦應會樂於花兩分鐘看完一則工程數學動畫。
- **增進教學效果**：計畫主持人通過製作工程數學動畫，可以評估動畫對學習成效的影響。由問卷分析與前後測結果得知，動畫確實可以提高學生們的理解和記憶。由李克特五等尺度量表之問卷分析結果得知，問卷分數達 4.69 分，亦即同學們的問卷學習回饋之平均成績是屬於「非常好」的等級。
- **設計出多樣化暨多媒體化的教材**：研究成果已開發出系列之新樣式的工程數學教材，並已安置於 YouTube 開放式課程平台上，動畫總數已超過 200 個，均可免費提供給對工程數學的學習有興趣之學生們參考，這些教材可應用於課堂講授、在線學習或自主學習。本計畫所提供之動畫教材，可進一步達成工程數學教材之多樣化暨多媒體化的呈現。
- **有助於改進教學方法**：所製作的白板動畫，可透過課程設計和課程融入，改進工程數學課程的授課方式。課程中融入手寫動畫的動態演示，可展現出獨特之個性與風格，是具有豐富情感之創作，能引起學生們的注意，增加學習的樂趣，並提高記憶效果。

總之，製作工程數學動畫，使學習更具有吸引力、更有效且更有趣。這項研究成果有助於克服工程數學在教學中的挑戰，並促進學生們對工程數學的深入學習。

二、研究問題(Research Question)

本計畫旨在開發出工程數學動畫教材，為確保教材能夠達到自訂之教育目標並有效傳達工程數學概念，故專注於以下問題進行教學研究。本計畫已透過李克特五等尺度量表問卷、前後測成績及質性分析，證明學生們透過動畫，更容易理解和應用工程數學的各種概念。本計畫之研究問題包括：

- **探討教學效果**：探討工程數學動畫，如何影響學生對工程數學的理解和學習成效。
- **了解學生參與度**：學習過程中，探討工程數學動畫如何影響學生們的學習參與度和興趣。
- **動畫設計風格與內容**：研究那些較佳的動畫風格可以促進學習，又動畫內容需能準確涵蓋工程數學之相關主題。

- **動畫之可及性**：所完成的動畫之可及性是透過 YouTube 來完成，對 YouTube 上的同學來說，應可透過 YouTube 檢索功能，方便、免費且自由地瀏覽本計畫所完成的工程數學動畫。
- **反饋和評估**：會以問卷、前後測成績及質性分析，評估學生們對動畫的反應和學習成效。

以上教學研究問題的思考，可以協助計畫主持人進行工程數學動畫教材的設計、製作與評估等面向，亦有助於在 112 學年度以後持續改進動畫教材的參考，以確保所完成的作品能提升學生們對工程數學的理解和應用能力。

三、文獻探討(Literature Review)

本計畫之推動，是以 107 至 110 學年度教育部教學實踐計畫案[1-4]之研究成果為基礎，新增 200 餘個工程數學動畫，用以強調學習重點，增進學習動機，吸引同學們的目光，使自學工程數學的學生們有機會進一步進行深入學習。計畫主持人在 YouTube 開放式課程平台上，已建立播放清單，同學們在播放清單中進行關鍵字的搜尋，能很快找到擬學習的單元之動畫教材。

由文獻探討得知，近年來，科技部亦曾補助與動畫製作相關之計畫案[5-9]，類似之計畫案教育部也會以經費支持[10-14]，亦有不少博士論文曾進行動畫相關議題之研究[15-18]。計畫主持人所建立之動畫，旨在引導學生進行自主學習，使學習者能獲得邏輯分析的能力，故影音教材或講義中，均會清楚介紹方程式的由來並說明其解析與應用方式。主持人具備以淺顯易懂的方式清楚講解複雜問題的能力，故所完成的工程數學教材，同學們均樂予推薦，其使用見證如表 1 所示，這些見證可歸類為質性分析成果。

關於科技融入教學或探討教學策略的文獻非常多，Amos[19]認為 YouTube 是自學者的熱門場所，且為課堂外強大的教育工具。Lyon 與 Magana[20]建議教授數學模式的建立時，老師應留意教學策略。Muhammad 和 Srinivasan[21]曾提出問題導向的教學策略，學生們在工程數學的學習上因而有較佳的表現。Lohgheswary 等人[22]的研究認為，Mathcad、Maple 和 MATLAB 等工具對線性代數的教學會有正面的效益。Noor 等人[23]引用符號運算軟體作為交互式學習工具，結果顯示此一工具有助於增進工程數學的學習興趣。Ambikairajah 和 Tisdell[24]引用線上測驗系統，評估其在教學上之適用性，結果顯示學生們的滿意度顯著提高。Figueroa-Cañas 和 Sancho-Vinuesa[25]的研究認為，Wiris 線上測驗可以提高工程數學的學習成效。Cheong 與 Koh[26]提供虛擬學習的整合實驗室環境，教授 Fourier 分析原理，此可提升學習者之學習動機與學習成效。Pattier[27]曾針對西班牙 41 個最成功的 YouTube 科學教育頻道進行分析，獲得 YouTube 科學頻道的影響力很大，且將持續積極發展的結論。Marchisio 等人[28]引用先進的計算機環境，藉由持續的互動，建構學生們的數學知識和解決問題的能力。Yelamarthi[29]是以學習者為中心，融合工程、數學和程式設計，改善大二學生的學習。Marsudi 等人[30]在 Covid-19 大流行期間，發現若能控制學生的初始能力，則使用 YouTube 作為學習媒體對學生的數學成績會有積極的影響。Irawan 等人[31]在流行病傳播期間，將所錄製的教學影片上傳至 YouTube，並獲得學生們的正面評價。Milovanovic 等人[32]在數學的教學上，引用 Flash 多媒體動畫，學生們表示對這種教學方式非常感興趣。Sharma 等人[33]曾針對印度的小學生、中學生、大學生和教師進行調查，認為 YouTube 帶來教育的創新性與創造性，使學習和教學變得簡單。Rohendi 等人[34]的研究指出，多媒體動畫能夠解釋工程數學中的抽象概念。Ejimonye 等人[35]是將 2D 動畫應用於奈及利亞大學的經濟學與數學相關之教學中，研究結果顯示動畫教材顯著提升了學生之後測成績。Sin 和 Al-Asmari[36]將 3D 動畫融入電子工程之課程中，同學們也相當支持此一教學模式。Jafar 等人[37]以教學影片輔助數學的翻轉教學，並獲得肯定的結果。Tisdell[38]的研究認為，學生多認同使用 YouTube 工程數學教學影片確實有助於提升學習成效。Tadbier 和 Shoufan[39]嘗試提出一些研究方法，分析 YouTube 教育頻道的排名。Winangun 和 Fauziah[40]曾提出科學教育之課程設計構想，期能藉由結合科學、工程、技術、及數學，以提升理工科系學生的素養。相關之研究，仍有許多，不勝枚舉。

自 2003 年起，計畫主持人每個學期均會向中華大學或教育部，申請執行一個數位教材開發計畫案，至今已順利執行過 40 個相關之計畫案，且從未間斷。計畫執行過程中，計畫主持人是將資訊科技融入教學活動中，已逐步實現了「以學習者為中心」，並引用「問題導向學習法」、「資訊科技融入教學法」、「設計教學法」、「思考教學法」和「自學輔導法」等之教學原理與內涵。目前已建立一系列的優質工程數學(一)(二)(三)(四)之開放式課程教材，並在 YouTube 上經營工程數學之教學社群 https://goo.gl/QysvnW，已廣受學生們的青睞。

由圖 1 至圖 6 之關鍵字「工程數學一」、「工程數學二」、「工程數學三」、「工程數學四」、「工程數學動畫」、「工程數學課程優選」的 Google 檢索排名常位居前兩名得知，申請人所建立的工程數學教材仍持續普遍受到學生們的重視。另外，至 2023/09/18 止申請人在 YouTube 所建立的工程數學教學社群 https://goo.gl/QysvnW，已有 3,790 位讀者訂閱，社群中訂閱者的提問，申請人均會盡可能在 12~24 小時內加以回覆，讓學生們可以獲得即時的回饋。歷年來許多訂閱者的留言均表示，此一 YouTube 教學社群對其工程數學的學習，的確相當關鍵且有幫助，如表 1 所示。此一質性分析結果，更加肯定透過 YouTube 進行工程數學的教學是有意義的。本計畫案所擬訂之研究課題，應有助於進一步提升自學工程數學者之學習成效。

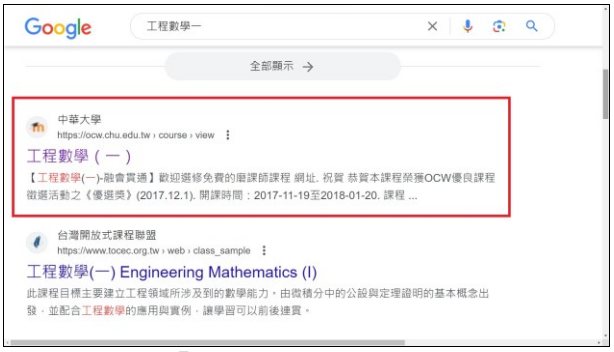

圖 1　關鍵字「工程數學一」之 Google 檢索排名為第 1 名(2023/09/18)

圖 2　關鍵字「工程數學二」之 Google 檢索排名為第 2 名(2023/09/18)

圖 3　關鍵字「工程數學三」之 Google 檢索排名為第 1 名(2021/12/16)

圖 4　關鍵字「工程數學四」之 Google 檢索排名為第 1 名(2023/09/18)

圖 5　關鍵字「工程數學動畫」之 Google 檢索排名為第 1 名(2023/09/18)

圖 6　關鍵字「工程數學課程優選」之 Google 檢索排名為第 1 名(2023/09/18)

表 1　2018 年至 2023 年工程數學開放式課程之使用者見證

暱稱	使用者見證	回應日期
Albert Lei	It’s a good video to demo the idea, many appreciate.	2023/09/18
貓貓	謝謝老師	2023/09/18
Chocolate Pun	讚	2023/09/18
Yao Ting Liu	謝謝老師挑選這麼有深度的題型	2023/09/16
曜庭劉	本想請教一同學習的同學 沒想到老師親自回答 非常清楚 謝謝親切的教授指教	2023/08/30
97 Deng	謝謝用心的老師	2023/08/03
97 Deng	謝謝老師用心製作的影片	2023/07/31
Wolf	老師謝謝您	2023/07/20
hi	感謝老師無私的分享	2023/06/28
Jun Lun Wang	感謝老師～看一次就懂了	2023/05/21
lin lin	謝謝老師的新影片	2023/04/03
徐安駿	謝謝老師，最喜歡你的工數課程了	2023/03/30
王小明	教學解說的詳細又清楚，棒棒噠	2023/01/11
大饅頭	很謝謝老師的用心回覆	2022/12/20
優質妙妙屋	老師上的很好！謝謝老師	2022/12/05
摩羯座	謝謝老師，獲益良多	2022/12/05
宋孟樺	老師好，我中原土木的學生，您的教學影片對於轉系的學生非常受用，希望老師這些影片可以持續下去	2022/11/17
噬靈滅影™	感謝老師教學，聽一遍複習一遍就通了~~	2022/11/17
one punch	感謝老師，第一次看到有老師用動畫方式提供教學，可以讓人更了解工數	2022/10/24
家瑋 劉	大推老師的課 真的學很多	2022/10/24
傅郁翔	非常受用，謝謝老師。	2022/09/29
lin lin	謝謝老師的教學	2022/09/15
Wolf	非常有幫助喔！	2022/09/07
Lin YuKi	謝謝老師	2022/07/22
魏廷栴	真的超級屌	2022/04/17
Dan’s Studios HN	You may not believe me but I'm a spanish speaker and I only know around 7 words in chinese but it was so clear that I actually understand what you explain. Thank you so much!!	2022/03/12
Oscar Franciscisco Hernandez Ortiz	ありがとうꉂ□ˊᵕˋ.♡ [譯] 謝謝你ꉂ˃ᵕ˂.♡	2022/02/11
Chris Jiang	相見恨晚，很好的教學 謝謝這麼用心的老師	2021/12/01
Dj Jd	太神啦~~~~	2021/11/06
陳思亭	謝謝老師!! 終於懂線性 ODE 了 QvQ	2021/11/01
太帥了健	謝謝呂教授 在中華大學的四年覺得您教得最好	2021/10/22
吳法吳天	真希望我們學校有這麼好的工數老師	2021/10/19
Che-Hsien Su	老師您的講義和影片都十分精美且詳細！真的十分感謝您！	2021/08/25
嘿嘿鋼琴廢職人	老師的教學非常詳細!!	2021/08/07
何冠良	在準備研究所考試的時候搜尋到這一系列的影片，有幫助到我，謝謝。	2021/07/28
trtcxu	以前上課老師都沒提到奇異解就是通解的漸進線…謝謝老師的說明…	2021/07/19
詹廷嘉	謝謝你 你是全台灣最棒的教授 你救了我的工程數學	2021/06/12
Marco T	Thank you for your contribution, since mathematics is a universal language, I will always understand. good video!, greetings from Mexico	2021/06/10
WJ Fan	謝老師，因為您的課，讓我考上研究所了。	2021/06/04
Brian Cheng	終於找到了，超感謝老師把複數相除幅角相減，複數相乘幅角相加，講解這麼清楚	2021/06/01

暱稱	使用者見證	回應日期
Jenny Liao	非常詳細的介紹！讓人淺顯易懂，版書也非常好看！	2021/05/21
Victor Tai	非常詳細，感謝在考試前一天救了我	2021/04/10
織	原本課本是用別的方法，一直看不懂，老師的這個方法很好理解，謝謝老師！！	2021/01/06
An An	教的蠻不錯，感謝耶！	2020/12/15
Lian Qiao	简直太棒了！	2020/12/15
Robertsan	Ahora en español Gracias.	2020/12/15
Ming RJ	謝謝老師 受用無窮 每一步都很清楚	2020/11/11
Debin Lu	老师讲的太详细了，认真负责	2020/10/20
馮翊婷	謝謝老師，謝謝老師上傳那麼多非常有用的知識！教得真的很好！	2020/10/13
Lance Ker	呂教授太強了，受用無窮。	2020/10/08
Teris Ho	很清楚的解析	2020/09/30
曾世墉	真的很棒，是我看過 youtube 中解法最好的，我本身學機械的，熱力學篇中有篇章就是講格林定理，但我始終不理解，感謝你傳道，授業，解惑也。世界有你變的更好。	2020/09/29
羅子煬	可說是救了遠在雲林讀書的我的線性 ODE	2020/09/29
SSLuis98	Thank you so much Teacher!!! You have helped me a lot!!!. I cannot express how grateful I am right now. Thank you so much, please stay safe and take care :D	2020/09/29
冷火	感謝教授的影片教學，受益匪淺，教授講得真的非常清楚明瞭。	2020/09/21
of cake a piece	講得很清楚，謝謝老師.	2020/08/18
高維聖	謝謝老師，我大致上可以了解怎麼來的了，因為在解問題時遇到 LT 函數與未知函數相乘做 inverse Laplace transform 轉換成定積分形式時，會出現 g(t-τ)這個問題困擾我大概一年的時間，終於有一個比較好的解釋方法。	2020/08/18
yong yuan	谢谢！讲的清晰	2020/07/24
米國大神	謝謝老師的解說 非常清晰	2020/07/01
Omar Lucana Ramos	Sí entendí, muchas gracias	2020/07/01
xXCrozz	arigato gosaimasu	2020/06/24
aaa sodfkas	感謝 我期末直接考 90 過了	2020/06/16
楊璿	謝謝老師的詳細講解!	2020/06/16
冰室雪菜	非常棒的影片	2020/06/03
丂丂丂	老師的工數影片深入淺出 對於先修很有幫助👆	2020/05/29
Lance	大學工數老師完全不會教方程式的幾何意義 只有不停地在黑板計算冷冰冰的算式 都要看老師的影片來學習 非常感謝 講得真的很棒!!	2020/05/26
小凡	證明推導的很漂亮，精彩，謝謝老師分享	2020/05/21
告	我覺得字幕會擋到最底下黑板的字. 但是真的講得很好	2020/05/17
Adolfo García Narciso	Gracias, Profesor🔌. Saludos! MX	2020/05/13
達立	太感謝了!!!! 老師解釋的很清楚!	2020/04/15
Cerebro Matemático	Quizás no pude entender las palabras. Pero los números tienen lenguaje universal. Gracias profesor..! 😁	2020/04/15
1212 54564	感謝你這麼用心在製作教學影片，經過講解後我學習到了許多，希望可以持續更新下去!!!	2020/03/12
Felipe César	thank you, i don't speak your language, i'm brazilian. But it helped me a lot for a test	2020/03/07
耀	老師的講解非常詳細，字體又好看 準備究所剛好找到老師的影片，真的很棒 ! 考得還不錯，很期待放榜 先謝謝老師了	2020/02/29
小凡	老師好, 365 個日子在忙碌的催趕中, 又不知不覺地悄悄地流失	2020/01/25

暱稱	使用者見證	回應日期
	走過，近來老師是否依舊安好如意，且過著充實有意義的生活，一年多來受到老師許多的啟蒙指導，使學習有所增長，由衷感謝.	
China Wang	教的很好且平易近人,非常認真的老師! 感謝老師的分享!	2020/01/01
Peter Yu	感謝老師詳細的講解！	2019/12/03
我是ㄅㄅ	謝謝老師 講解得很好	2019/11/02
罐罐	加油窩 教授，看到你們做簡單易懂的分析，讓我這些看久了研究所題庫的高壓學生輕鬆不少	2019/10/29
SunnyBall1234	教授您好：看完了大部分影片，您真的講解的很好，這種用題目來讓我們思考公式的意義以及用法的方式，真的讓學習的人可以很快地融會貫通。希望教授您會再出影片！	2019/10/22
K Y	板書好工整啊!!	2019/10/22
SunnyBall1234	教授您解釋得實在太好！謝謝您！	2019/10/08
Kyle Jiang	謝謝教授的講解，很詳細!!	2019/10/06
Oapa 66	老師做的影片簡而易懂 非常棒!	2019/09/18
yenting Chou	感謝呂老師分享，解題技巧俐落，講解的又清晰，非常受用。	2019/08/31
陳太和	老師很認真	2019/08/15
yanpeng li	老师讲的真细致，太棒了。好多概念比如 Hankel 积分变换，弄了好久才搞明白。	2019/08/08
Eric Apple	字體工整、邏輯清晰，呂教授真的厲害!!感謝分享~~	2019/07/15
羅立渝	講的非常清楚 而且很有條理 謝謝您	2019/06/15
tabby wu	推導過程清晰易懂，謝謝您的教學!!!	2019/06/11
akila	感謝~講解十分清楚	2019/05/29
小凡	感謝老師在白忙中抽出時間給予解答疑惑	2019/05/11
chin Huang	原來如此 謝謝老師	2019/04/08
林仔新	感謝教授指導 幫助我超多^_^	2019/03/17
陳太和	誨人不倦	2019/03/14
chenxu zhao	老师讲得不错 板书也很认真 好老师	2019/02/16
Xri yang	瞭解了！感謝老師回答	2019/02/14
卓立	懂了!謝謝老師!	2019/02/13
Zi Fang	講得很清晰，對於自學的學生有很大幫助	2019/02/09
Hero Chiu	感謝老師 讓我以前不清楚的地方 更加清楚了	2019/01/29
Zhi SUN	书上都仅仅是结论，从来不知道是怎么来的。今天我终于是明白了，推导实在是太详尽了，吕老师辛苦了啊！果断订阅！！！	2018/12/23
Lucky man	很感謝這位老師拍的這些影片 讓我真的對工數有更佳的理解 希望老師的頻道不要突然不見 哈哈哈 我介紹很多同學來來看這些影片 好評真的不少阿	2018/12/18
Yan Sheng	感謝您 我懂了	2018/12/07
蔡哥我愛	老師，謝謝您，學生受益良多~	2018/12/01
TePei Lin	真的很棒，謝謝辛苦的教学。	2018/12/01
lin lin	非常感謝老師如此認真的錄製工程數學教學影片.. 老師清晰深入的說明讓我可以真正學到什麼是工數.. 以前都是背公式不太懂為何如此.因此學的很痛苦.. 看過老師錄的很多仔細說明講解影片後有種恍然大悟的感覺.. 真的要謝謝老師無私的奉獻.造福無數的學子	2018/11/08
Justin Weng	講得很清楚	2018/11/07
eting lin	謝謝老師!!!!!很棒的講解~!!!	2018/10/22
Z Xu	果然还是例题最能说明方法啦~	2018/10/07
peng penggy	喜欢，支持老师	2019/09/25
石辰	感謝老師的教學用心!非常懂我們學生要的是甚麼:)	2019/09/19
201801409 Gerardo Prado Chojolán	Great explanation :)	2018/08/09
張晏誠	謝謝教授，讓您這麼晚還為我解惑，謝謝	2018/07/04

暱稱	使用者見證	回應日期
Rob	老師的教學很認真、詳細，直接命中學生容易困惑的地方。不像我以前大學教授都模糊帶過。現在有這麼認真教學的教授很少了，真希望我以前的工數是給您教的。	2018/05/15
高均成	講得很清楚!!	2018/04/27
Kami Chen	講的很詳細！懂了	2018/04/23
Yuzhen Huang	不论是讲课内容还是板书 思路都非常清晰 谢谢老师上传视频！	2018/04/19
Peter Pan	謝謝老師把我對於傅立葉轉換前面的 1/2*pi 做一個完整的講解!	2018/04/12
Peter Pan	台大生路過，覺得教得很好	2018/04/09
蔡啟文	非常詳細！工數的救星	2018/04/02
Yassir Maataoui	I don't understand Chinese but the video is very helpful, thank you very much!	2018/04/02
Peter Pan	If you understand it, you will find that this professor is awesome.	2018/04/02
CHE CHE	以我數學系來看 真的教的很棒!	2018/03/27
Bulooo Mister	很棒阿，很用心	2018/03/22
YERI	老師講得很好 只是我要多練習題目才會熟練	2018/03/14
lmhz lou	非常給力！Very useful for me!	2018/03/14
李坤助	真清楚 謝謝老師	2018/02/22
彭成康	我的救世主阿 很好懂~~	2018/01/16
YERI	看了就會了 感謝!	2018/01/07

四、教學設計與規劃(Teaching Planning)

藉由 32 年的教學研究成長，以及 Flash 互動式動畫的製作經驗，本計畫已將工程數學之重點，以動畫方式加以呈現。所製作的工程數學動畫是以 VideoScribe 手寫動畫軟體完成的，所完成的工程數學動畫已超過 200 個。在實體課程中，可藉由與學生們的互動，持續了解學生們的工程數學之學習困擾，並以動畫方式為同學們解惑。本計畫之教學研究成果，已以開放式課程的模式，**將工程數學動畫影片分享至 YouTube 網路上眾多的學習者，此為最直接有效的公開發表形式，且亦有助於擴散教學效能。**計畫主持人之研究主題與實體課程之「工程數學(一)」和「工程數學(二)」有關，在課程計畫書中已詳述教學目標、教學方法、成績考核方式、各週次課程進度、學習成效和評量工具等。所擬定的研究設計內容，可同時照顧好實體課程和開放式課程中之學習者。

本課程之教學設計與規劃如圖 7 所示，有引用其中之線上單元測驗安排前測與後測，分別安排工程數學(一)和工程數學(二)進行 10 次與 12 次的知識點小測驗之前測與後測。其中工程數學(一)之前後測成績分別為 48.61 分與 92.39 分，工程數學(二)之前後測成績分別為 47.77 分與 90.33 分，如圖 8 與圖 9 所示。計畫主持人有調整 Moodle 的測驗功能，使同學們能獲得自學的快樂，包括：

- 作前後測的同學僅知道自己的測驗總分，亦即學生們並不清楚哪一題答錯了。
- 每次的前後測均使用相同的題目，期能保持測驗前後之難易度完全相同。
- 學期中之任意時刻均可進行前後測，故學習較不受時空的限制。
- 後測次數不限制，使同學有機會體驗後測成績逐漸進步的喜悅。
- 不會要求每位學生均需參與前後測，但統計資料僅會納入有參與前後測的同學進行學習成效分析。

本計畫有針對工程數學(一)和工程數學(二)之前後測成績進行 p 值（p value）檢定，所得 p 值分別為1.8×10^{-11}與1.5×10^{-14}，均很接近零，亦即學生們的後測成績確實有顯著的進步。

在本計畫案的結案階段，有安排李克特五等尺度量表之問卷，問卷題目如表 2 所示。由分析結果得知，問卷分數達 4.69 分，如圖 10 所示，亦即同學們的學習回饋之平均成績是屬於「非常好」的等級。

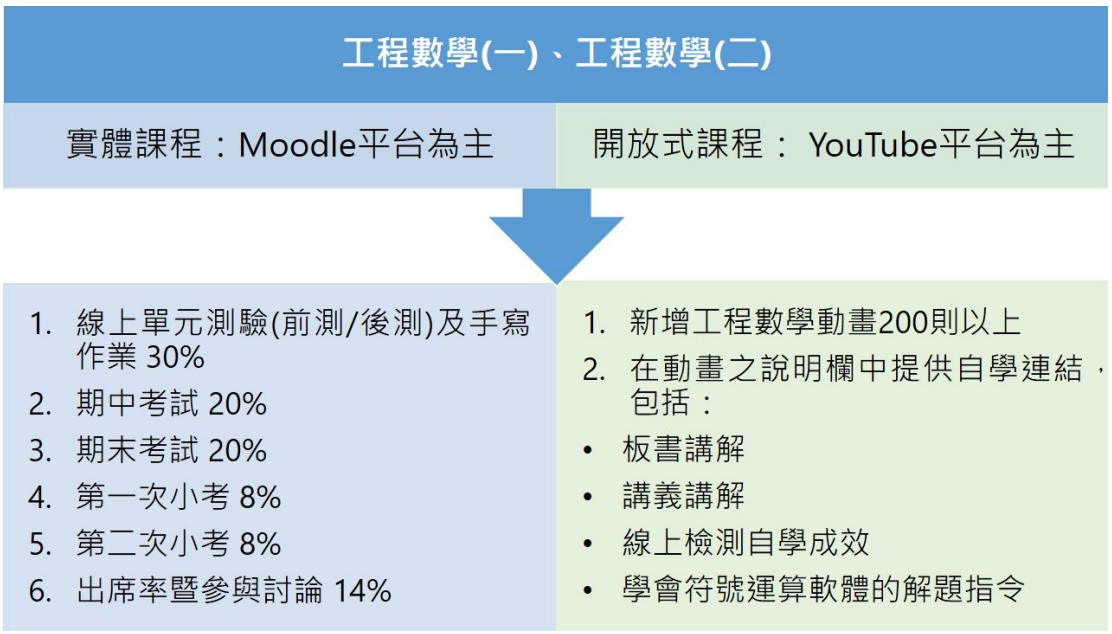

圖 7　本課程之教學設計與規劃

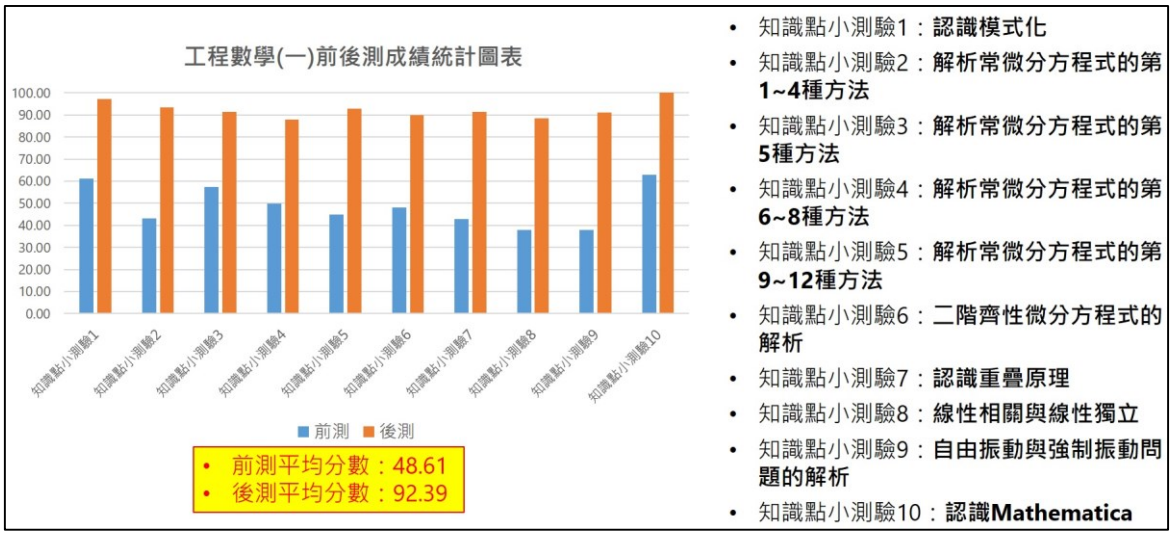

圖 8　111 學年度上學期「工程數學(一)」前後測成績統計圖表

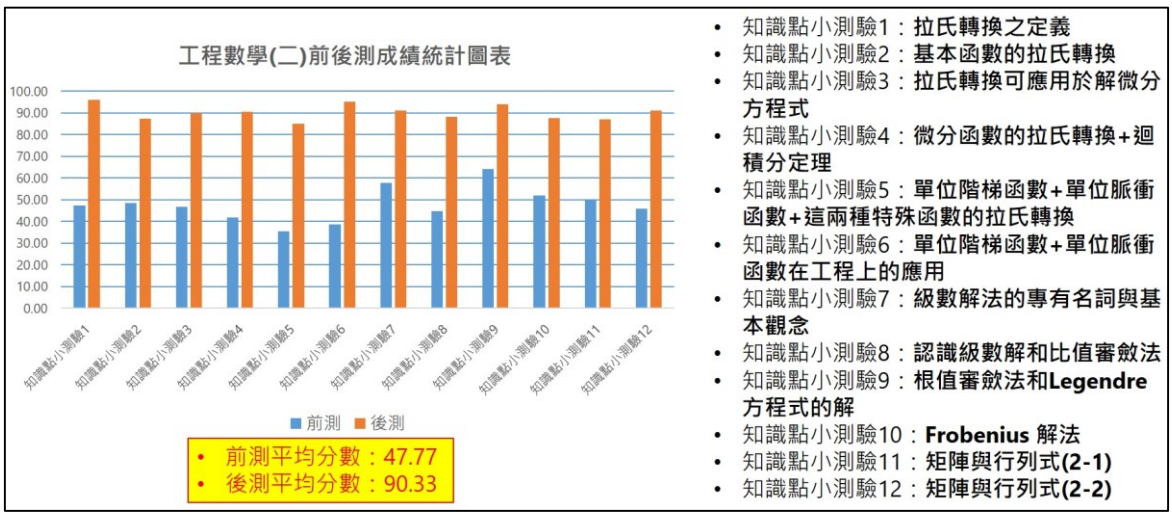

圖 9　111 學年度下學期「工程數學(二)」前後測成績統計圖表

表 2　關於工程數學動畫的學習成效分析所安排之李克特五等尺度量表的問卷題目

評分等級 / 問卷題目	非常同意	同意	普通	不同意	非常不同意
1. 教師開發之《工程數學》動畫教材能啟發我的學習興趣。					
2. 教師開發之《工程數學》動畫教材有助於提升我在該專業領域的知識。					
3. 教師開發之開放式《工程數學》動畫教材，有助於我調整我的學習進度。					
4. 教師開發之《工程數學》動畫教材能增強我的學習效果。					
5. 教師的教學態度熱忱、認真、負責。					
6. 我認為建立開放式《工程數學》動畫教材之教學型態，較傳統課程更具有學習效果。					
7. 教師開發之《工程數學》動畫影片清晰易懂。					
8. 教師開發之《工程數學》動畫影片下方所提供的超連結，對我的學習很有幫助。					

圖 10　「工程數學」所錄製的動畫影片之學習滿意度問卷調查結果

五、研究設計與執行方法(Research Methodology)

本計畫之關鍵為動畫的製作，因此以下說明動畫之製作過程。完成一部動畫需考慮許多面向，例如過程中需仔細規劃、創建、編輯和發佈。以下簡要說明動畫之完成過程：

- **確立目標和概念**：首先需確立製作動畫的目標和概念，希望傳達什麼信息，以及動畫擬講述的工程數學故事或概念是什麼。
- **創建故事腳本**：故事腳本的規劃會包括場景的安排和畫面的順序，亦需決定動畫的篇幅、視覺風格和內容。初期階段，計畫主持人曾透過瀏覽動畫範本，了解 VideoScribe 手寫動

畫之呈現技巧，先以模仿方式進行創作，逐漸調整為具有個人風格的動畫作品。

- **設計角色和場景**：根據故事腳本開始進行設計，相關內容包括主要角色、次要角色和場景設計等。VideoScribe 已能顯示中文，但有時會發生字型缺失的情況，其克服方法之一為透過簡報軟體 PowerPoint，將文字調整為所需之字型後，再將文字以背景透明的圖檔輸出，然後匯入 VideoScribe 即可解決字型缺漏的問題。
- **製作原稿動畫**：計畫主持人在動畫的製作上會考慮兩個關鍵，一是工程數學觀念的融入，二是動畫風格的挑選。例如可以挑選教室講授風格的場景，解說微分方程的解題技巧；同一解說過程，也可以引用太空冒險、球場運動等的場景進行解說。可根據所擬定的故事，開始製作動畫的原稿。VideoScribe 手寫動畫之場景安排相當豐富有趣，可自由挑選背景音樂，且每個動畫呈現的方式有手寫文字、平滑結束、超過極限後折返、跳躍、場景放大縮小等可供選擇，可據以靈活運用與創作。
- **搭配聲音和音樂**：需考慮是否需要添加解說聲音或音樂，這可以提高動畫的吸引力和融入情感。VideoScribe 手寫動畫中有兩百餘首的音樂可供挑選，計畫主持人通常會選擇輕快音樂當作背景音樂，音樂的挑選亦與所安排的場景有關，音樂有時是扮演動畫影片的靈魂。動畫影片選用 VideoScribe 所提供之背景音樂時，均符合版權要求，可順利上傳至 YouTube。
- **編輯和後期製作**：在完成動畫原稿後，需使用動畫軟體進行編輯和後期制作。這包括添加轉場時間、調整動畫速度、改進視覺效果、配音等。
- **測試和反饋**：在動畫完成之前，需進行多次測試以確保其流暢度，並請他人提供反饋意見。這有助於發現並修正問題。
- **影片輸出和解析度調整**：當已滿意動畫的最終版本時，需將它輸出為常見的影片格式，VideoScribe 之動畫影片輸出格式可選用通用格式 MP4，該通用格式可方便於分享和播放。影片解析度可調整為 HD(High Definition)格式，即高度清晰之 1,080 畫素。較清晰之動畫教學影片會較有利於觀賞，也易於檢視影像中之細部內容，此亦有利於吸引學生自學工程數學。
- **發佈和宣傳**：本計畫是將動畫上傳到 YouTube 平台，需確保使用適當的標題、描述和標籤來宣傳所完成的動畫。
- **監控和回應**：需留意觀眾的反應，應盡可能及時回應他們的評論和反饋，並考慮進一步改進個人之動畫技巧。

完成動畫是一個具有挑戰性但有趣的過程，它需要創造力、技術和耐心。這個過程既耗時又費力，且創作過程有時會遇到瓶頸。經過計畫案這一年來的努力和訓練，計畫主持人已逐漸能有把握創建出引人入勝的動畫作品，並自 112 學年度起，持續發表新的工程數學動畫作品。

自主學習為本計畫最重要之核心理念，為引導學生能自主學習，每個動畫安排於 YouTube 平台後，在說明欄中會給予學習指引，這些學習指引包括同一問題的板書講解、解說講義、線上測驗及符號運算軟體講解等，希望藉此安排，學生能獲得觸類旁通的學習機會。圖 11 與圖 12 是分別在 YouTube 教學平台以動畫簡介《工程數學(一)》和《工程數學(二)》；圖 13 是所建立的工程數學動畫播放清單；圖 14 至圖 17 分別為[教室講授風格]、[運動風格]、[遠距教學風格]、[精簡講授風格]等不同動畫風格之運用；工程數學動畫中均會呈現詳細之解說內容，如圖 18 所示；圖 19 顯示，動畫下方之說明欄位會提供教材下載、瀏覽板書解答、線上檢測自學成效、學會符號運算解題方法、工程應用範例等；由圖 20 得知，點選動畫下方之[符號運算軟體講解]，會呈現 Mathematica 之詳細解說內容；圖 21 旨在說明，點選動畫下方之[板書講解]可瀏覽同一例題之板書詳細解說影片；線上自學者若想了解自學成效，則可點選圖 22 所示之動畫下方的[互動測驗影片]，該連結會引導自學者進行線上測驗；點選動畫下方之[解題講義]可瀏覽同一例題之解說講義，如圖 23 所示；由圖 24 得知，點選動畫下方之[工程應用範例]，會引導自學者瀏覽同一問題之工程應用方式。

圖 11　在 YouTube 教學平台以動畫簡介《工程數學(一)》

圖 12　在 YouTube 教學平台以動畫簡介《工程數學(二)》

圖 13　所建立的工程數學動畫播放清單

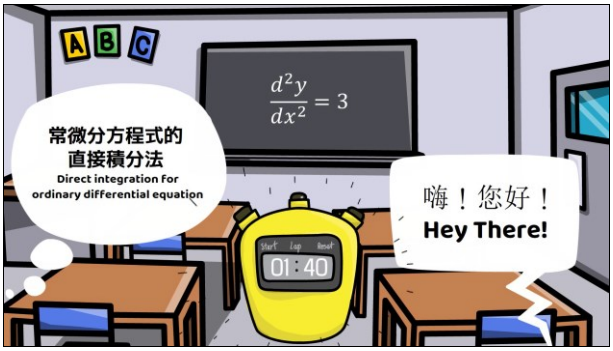

圖 14　具有教室講授風格的動畫

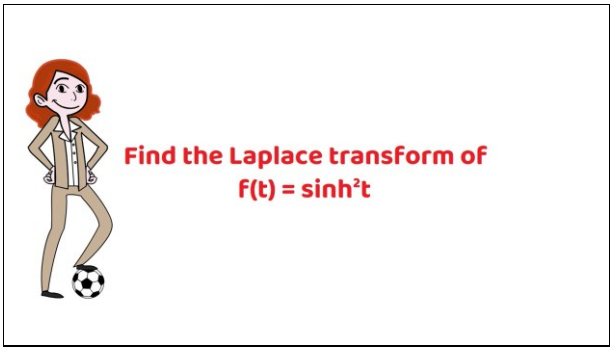

圖 15　工程數學融入運動風格的動畫

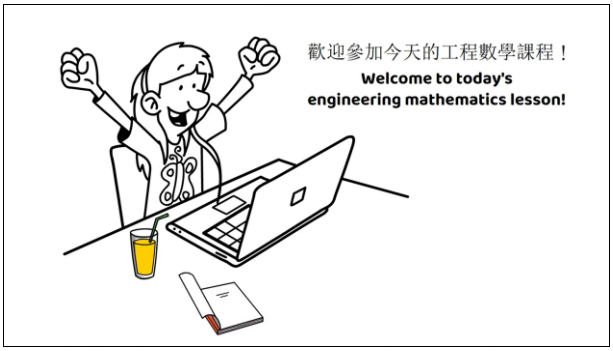

圖 16　有遠距教學風格之工程數學動畫

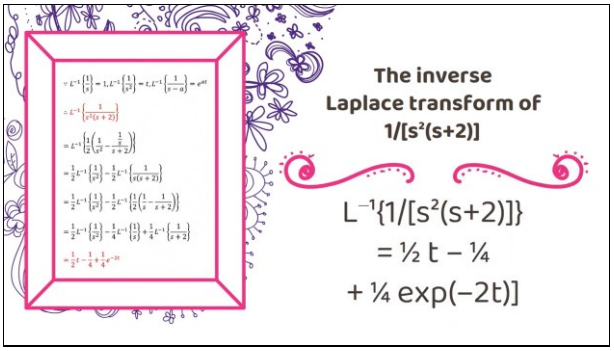

圖 17　呈現精簡講授風格的工程數學動畫

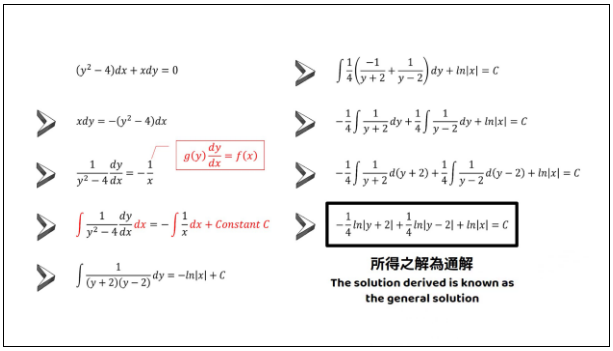

圖 18　工程數學動畫中會呈現詳細解說內容

圖 19　動畫下方之說明欄位會提供教材下載、瀏覽板書解答、線上檢測自學成效、學會符號運算解題方法、工程應用範例等

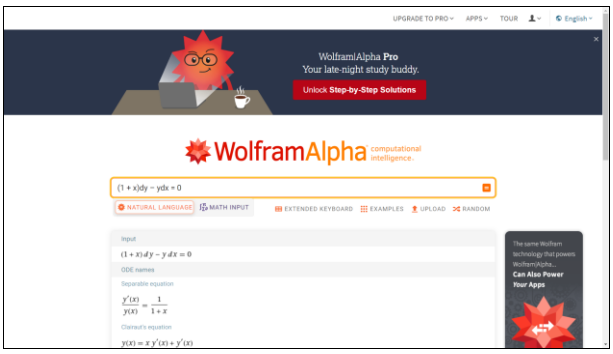

圖 20　點選動畫下方之 [符號運算軟體講解] 會呈現 Mathematica 之詳細解說內容

圖 21　點選動畫下方之 [板書講解] 可瀏覽同一例題之板書詳細解說影片

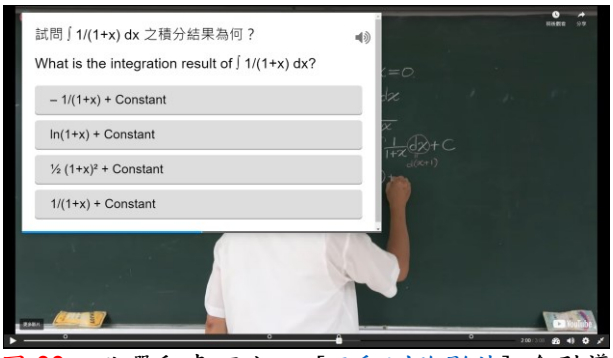

圖 22　點選動畫下方之 [互動測驗影片] 會引導自學者進行線上測驗，用以了解自學成效

圖 23　點選動畫下方之 [解題講義] 可瀏覽同一例題之解說講義

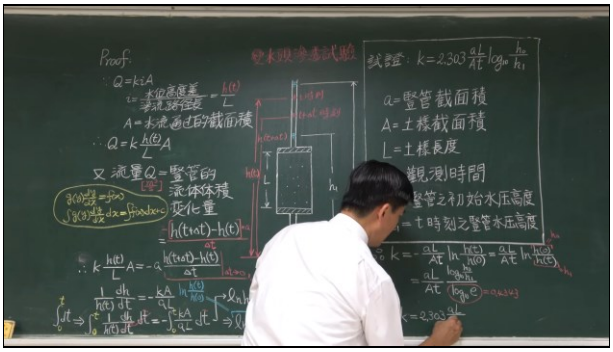

圖 24　點選動畫下方之 [工程應用範例] 會引導自學者瀏覽同一問題之工程應用方式

六、教學暨研究成果(Teaching and Research Outcomes)

(1) 教學過程與成果

關於實體課程之學分數、修課人數、通過人數、教學評量、學習成效評量等主要教學過程與成果包括：

- **工程數學(一)**：2 學分，54 位同學修課，共計 48 位同學獲得及格以上分數。
- **工程數學(二)**：2 學分，58 位同學修課，共計 49 位同學獲得及格以上分數。
- **教學評量**：採問卷評量與質化評量。
- **學習成效評量**：採多元評量，包括前後測評量、手寫作業評量、出席率評量、討論評量、紙筆測驗搭配線上測驗之小考、期中考與期末考評量等。
- **已完成 200 個以上之工程數學動畫教材**：超出計畫案原初規劃之 100 個動畫，目前動畫教材數量之計畫案成果達原初規劃之兩倍以上。

本校教學發展中心亦會安排教學評量問卷，其問卷題目如表 3 所示。由問卷結果得知，111 學年度工程數學(一)與工程數學(二)之教學問卷分數分別為 90.8 分與 93.1 分，如圖 25 與

圖 26 所示。可見各種面向之教學問卷，授課教師仍可獲得修課同學們的高度肯定。

表 3　教學發展中心教學評量問卷題目

評分等級 / 問卷題目	非常同意	同意	普通	不同意	非常不同意
1. 老師上課時會說明課程的學習目標					
2. 老師上課態度熱忱、認真、負責					
3. 老師所採用之授課教材或教學方式能啟發學生學習					
4. 老師能依學生學習的反應而調整教學					
5. 老師在課堂內外樂於與學生討論課業					
6. 老師會依照課程大綱進行授課與評分					
7. 課程整體規劃與教學能培育課程所設定之核心能力					
8. 課程內容設計有助於提高我對課程學習之興趣					
9. 課程教授方式有助於提高我對課程專業知能之吸收					
10. 我已確實學習到課程有關的專業知識					

圖 25　111 學年度工程數學(一)之教學問卷分數為 90.8 分

圖 26　111 學年度工程數學(二)之教學問卷分數為 93.1 分

(2) 教師教學反思

計畫主持人雖已有 32 年的教學資歷，但仍然不斷反思如何改進教學方法和提高學生的學習成效。以下是一些教學反思：

- **評估學生的理解**：需定期評估學生對工程數學基本概念的理解，可使用測驗、作業、問題導向、課堂討論或問卷等多元評量的方式，確保學生掌握了基本概念。
- **分析學生的表現**：仔細分析學生的測驗結果和作業，以確定哪些主題或概念需要進一步的強調或解釋。
- **回顧教學方法**：反思自己的教學方法，問自己是否使用了多元化的教學策略，以滿足不同類型之學生的需求。可考慮是否有更好的方法，可用以解釋複雜的工程數學概念。
- **設定學習目標**：在每堂課之前，明確設定學習目標，以幫助學生明確了解他們將學到什麼，以及為什麼重要。
- **提供即時反饋**：在課堂中提供即時反饋，幫助學生澄清錯誤的邏輯分析觀念，並指導他們探索正確的方向。這可以通過課堂討論、示範和練習來實現。
- **鼓勵主動學習**：創造一個鼓勵主動學習的環境，鼓勵學生提問、討論和解決問題。提供資源，讓學生們可以自主學習。

- **建構多元化教材**：使用多種教材，包括書籍、線上資源、工程案例和數學應用實例等，以豐富教學內容。
- **持續專業發展**：不斷提升自己的教學知能，可多參加教學研討會、培訓課程，並與其他教育專家互動分享經驗。
- **鼓勵學生提供反饋**：可定期討論同學們的意見。這可以幫助老師調整教學方法，以滿足學生們的需求。
- **關注學習氛圍**：確保教室或線上學習環境是正面且具支持性的，使學生們能感受到被尊重和受鼓舞。
- **自我評估**：不斷自我評估，問自己的教學方法是否達到了預期的結果，並尋找改進的機會。

教學反思是一個不斷改進的過程，有助於持續提升工程數學的教學效果，並確保學生能夠成功掌握重要的工程數學概念和知能。

(3) 學生學習回饋

計畫主持人在實體課程之教學過程中，曾在工程數學(一)與工程數學(二)之 Moodle 教學平台中，分別安排 10 個與 12 個知識點小測驗，進行前測與後測，用以了解學生們的學習成效，每個知識點小測驗之題目數量為 5~25 題。前後測所使用的題目完全相同，但學生們並不清楚曾答錯哪些題目，僅知道自己的答題分數。此一盲測安排，應有助於準確得知學生們之學習成效。基於此，工程數學(一)(二)的前後測成績如圖 8 與圖 9 所示，其中工程數學(一)之前後測平均成績分別為 48.61 分與 92.39 分，工程數學(二)之前後測平均成績分別為 47.77 分與 90.33 分。另外，由如圖 10 所示之李克特五等尺度量表之問卷分析結果得知，問卷分數達 4.69 分，亦即同學們的學習回饋之平均成績是屬於「非常好」的等級。以上努力顯示，本計畫所完成的動畫，極有助於提升工程數學之學習成效。

七、建議與省思(Recommendations and Reflections)

製作工程數學動畫是一個相當具有挑戰性但又很有潛力的目標，經過這一年的努力，個人有以下建議和省思，期能持續幫助自己和他人，能成功製作出優質的工程數學動畫。

建議：

- **建立清晰的目標**：首先需要確立動畫的目標和受眾。本計畫所製作的工程數學動畫是擬應用於工程教育，且學生們已具備微積分之基本能力，故會跳過微積分，直接介紹微分方程等問題之解析方法。其他學科之動畫製作，亦可考慮以上原則。
- **熟悉工程數學內容**：因計畫主持人已有 32 年的教學經驗，了解學生們的學習需求，故能深入淺出的呈現工程數學內容，亦能確保動畫的準確性和教育價值。
- **故事腳本設計**：以說故事的方式介紹工程數學是可以持續努力的方向，需建立故事腳本，用以計畫和組織動畫。故事腳本應包括場景、角色、對話和主題順序的視覺化效果等。
- **適當的視覺風格**：主持人已挑選出數個適合個人的視覺風格，包括教室上課風格、運動風格、太空探索風格、筆記風格等等，有些動畫可能需要更具技術性的風格，而其他則需要更加簡化和易懂的風格。
- **清晰的語音和文字**：如果使用語音或文字解釋，需確保它們清晰、易懂，並符合受眾的語言水平。本計畫所完成的動畫，會盡可能以中英文同時並列的方式進行解說，使有利於國際化之應用推廣。
- **互動和反饋**：YouTube 的留言區，可與學生進行互動，老師可據以提供即時反饋，這方面的努力，可以加強學生們的學習體驗。計畫主持人已嘗試在 YouTube 說明欄中，提供與教學影片相關之板書、講義下載、符號運算軟體之解題、線上測驗、工程應用範例等超連結，但仍有許多面向值得持續努力。
- **音效和音樂**：選擇適合的音效和音樂，可以增加動畫的情感和吸引力。計畫主持人認為，

需找到新的音樂進行配樂，使動畫影片具有新鮮感，故建議使用 AI 創作音樂，或向音樂公司購買有版權的音樂，以豐富配樂。

- **平衡簡單和複雜**：平衡動畫中之簡單和複雜元素，使其具有整體的美感，仍是值得精進的目標。最重要的是確保同學們能透過動畫，理解工程數學的基本概念，同時也能拓展學生們的思維。
- **測試與反饋**：計畫主持人所完成的動畫，會嘗試進行多日多次的測試，修正並調整，學生們也會提供反饋意見，這些努力均有助於發現和解決潛在的問題。

省思：

- **目標評估**：製作好動畫後，需評估是否達成預設之目標，這可以幫助個人改進未來的動畫製作方式及規劃目標。
- **持續學習並精進**：動畫製作是一個不斷學習和改進的過程，每次製作好一部動畫後，均可反思所使用的動畫表現方式，還有哪些方面可以持續精進。
- **留意觀眾反應**：需密切關注同學們的反應和反饋，這將有助於了解同學們對所完成的動畫之感受，可據以做出相應的調整。
- **技術提升**：學然後知不足，目前仍有很大的空間可提升個人的動畫技術，需學習新的工具和技巧，以創造出更具有吸引力和價值感的內容。
- **建構多元化內容**：可考慮創建多種不同主題和難度水平的動畫，以滿足不同受眾的需求。
- **合作與分享**：可與其他教育界先進、專業人士和創作者合作開發動畫，以獲得更多意見和想法。

製作工程數學動畫需要有耐心、創造力和技術，它可以成為一個極具教育價值和創意表達的媒介。不斷反思和改進，是持續提升動畫製作技能的關鍵。

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附件(Appendix)

本計畫之兩篇研究成果已順利於 2023 年 6 月刊登於 Engineering Proceedings 期刊中，該期刊為 Scopus 收錄之重要期刊，摘要資料及其詳細本文內容如以下所示：

1. Lu, John C.-C., 2023, "**Creating Effective Educational Videos on YouTube in Higher Education**," Engineering *Proceedings*, ISSN: 2673-4591, Vol. 38, No. 1, 32, doi:https://doi.org/10.3390/engproc2023038032. (This work is supported by the Ministry of Education of Taiwan, Republic of China, through grants PEE1101210 and PEE1110397.) (**Scopus**)
2. Lu, John C.-C., 2023, "**Using YouTube as an Effective Educational Tool to Improve Engineering Mathematics Teaching during the COVID-19 Pandemic**," Engineering *Proceedings*, ISSN: 2673-4591, Vol. 38, No. 1, 24, doi:https://doi.org/10.3390/engproc2023038024. (This work is supported by the Ministry of Education of Taiwan, Republic of China, through grants PEE1101210 and PEE1110397.) (**Scopus**)

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Proceeding Paper

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John C.-C. Lu

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Proceeding Paper

Creating Effective Educational Videos on YouTube in Higher Education †

John C.-C. Lu

Department of Civil Engineering, Chung Hua University, Hsinchu 30012, Taiwan; cclu@chu.edu.tw

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Abstract: Educational videos have become an important part of higher education. Thus, it is necessary to discuss practical tips for creating high-yield educational videos. The electronic medium is integrated into traditional courses and serves as the cornerstone of many blended courses. Multiple studies have demonstrated that video is a highly effective educational tool for learning, particularly for hard-to-visualize processes and procedural education. Video allows learners to view content at their own pace and view on-demand materials repetitively. Video on YouTube can be integrated as a supplement to course content to provide targeted information and enrich the learning environment for students. In this article, creating an effective video on YouTube is introduced, providing examples of effective recording and integrating video into engineering mathematics courses on YouTube.

Keywords: educational video; YouTube channel; higher education; engineering mathematics

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1. Introduction

YouTube videos are commonly used in higher education. D'Aquila et al. [1] concluded that students viewed the videos primarily for exam review, and video usage improves student performance. Jackman [2] used YouTube in three psychology classes at the University of Trinidad and Tobago and found that YouTube can be used in tertiary education pedagogy. Hoa et al. [3] proposed building a healthy and positive YouTube Kids channel suitable for the characteristics of primary school students. Nabayra [4] investigated students' experiences with the use of teacher-created videos in learning mathematics online and revealed that teacher-created videos were helpful for students to self-assess their learning progress. Makruf et al. [5] concluded that Moodle was less optimal in the implementation and evaluation of learning in higher education. Hendriyani et al. [6] developed online learning videos to improve students' creative thinking skills. Bauk [7] discussed the benefits and challenges of international virtual exchange in teaching and learning at higher education institutions. Noetel et al. [8] systematically reviewed the effects of video on learning in higher education and concluded that videos were unlikely to be detrimental and usually improved student learning. Fyfield et al. [9] suggested that videos be accompanied by learning activities rather than watched passively. Miner and Stefaniak [10] compared instructors' and students' perceptions regarding the use of video during instruction. Kohler and Dietrich [11] showed that both social status and individual predispositions influenced the outcome of educational videos. Shoufan [12] tried to use viewers' ratings and participation to measure the quality of educational videos. The findings of Çelik et al. [13] showed that the most used social media tools were also used for educational purposes, and the most significant exception in this subject was TikTok. Boey et al. [14] investigated how the integration of technology contributed to the development of attributes or learner profiles suitable for the workplace and real-world performance while also meeting skill-based learning outcomes.

YouTube can be a powerful tool for education beyond the classroom. Educational videos can be easily uploaded to YouTube, and using these virtual teaching materials

has been highly favored by educational organizations. Many studies have shown the application and effectiveness of creating educational videos on YouTube. Therefore, the author has recorded more than 1800 teaching videos on engineering mathematics. Most recorded videos of teaching last less than 15 min and have been uploaded to YouTube for students to view for free. Without advertisements, students can concentrate on self-study. The synchronous class recording is avoided to improve the quality of recording teaching videos. The script writing, directing, and editing of self-recording videos are completed by the author, which saves time for editing. Sometimes, re-recording 3−5 times improves the quality of the teaching video, though most videos are recorded in one take. Each video deals with one theme to construct students' confidence through the thematic teaching materials.

In this article, the experience of recording high-quality teaching videos is shared. A questionnaire analysis was conducted on the effectiveness of teaching videos for 26 students in the engineering mathematics courses. The statistical analysis result showed that planning for learning was evaluated as favorably with a score of 4.81 on a 5-point scale. This shows the effectiveness of teaching videos on YouTube.

2. Effective Educational Videos

The video needs to be recorded using the fundamentals and principles of photography. Furthermore, it is also necessary to understand the golden ratio of the contents and the principles of art. The following are suggestions based on our experience with more than 1800 self-recorded teaching videos.

- **Why do I need to record teaching videos?** Making the classroom joyful and interesting is an important consideration. Attractive teaching videos are required for students to preview and review lessons at their convenience through teaching videos on YouTube. The instructional videos on YouTube are set to public mode, and the interference of advertisements is not allowed;
- **How do I make lesson videos for students?** It is required to be accustomed to recording instructional videos by camera and computer screen capture. Camera skills and computer screen capture software are demanded. The learning process may take several weeks;
- **What should I do if funds are insufficient?** Many teaching units on the campus can provide cameras or teaching software. Teaching equipment can be rented from the academic affairs office. Higher-priced equipment may not be required. Instructional videos can be recorded with a cheap microphone;
- **What should I do if there is no studio room?** The classroom is a suitable studio with a digital camera. A high-resolution digital camera is needed for recording. Synchronous recording with classes must be avoided to improve teaching video quality. In addition, when using an empty classroom, it is necessary to overcome the psychological barrier of no audience;
- **How to improve my digital literacy?** It is necessary to be motivated to learn new digital skills. Even though digital hardware and software are constantly evolving, video production skills have not changed much. There are good ideas for integrating new technologies into teaching by searching for 3C products;
- **Is the artistic effect of teaching video insufficient?** Students want to learn logical thinking and problem-solving from teaching videos rather than appreciate video styles. In addition, if the teacher writes mathematical symbols neatly, it helps students' learning;
- **What should I learn about digital software?** There are many kinds of digital software for making educational videos, such as Power Director, Camtasia, and MS Teams, which are the most commonly used. There are similar applications, and the choice depends on whether it is easy to obtain the licensed software;
- **No time to record instructional videos?** Teachers are usually busy. Therefore, only interest and enthusiasm can provide sufficient motivation. At the right time, in the right place, and with the right people, the teacher needs to complete the recording of

teaching videos. If teachers have enough time to record teaching videos, the quality and quantity of the videos can be gradually improved;

- **It is necessary to have an understanding of copyright law.** Teachers need to understand the copyright law. Although the copyright law has restrictions, it also allows protection. Therefore, teachers need to understand the law before recording teaching videos and collect the materials for recording the teaching video. If necessary, Creative Commons-licensed materials can also be used;
- **Personal capability.** Every teacher has different specialties and abilities. Teachers do not have to record teaching videos to achieve academic success with their abilities. The academic achievements required are multifaceted, and academic efforts in all aspects need to be appreciated;
- **Pre-arrangement of course planning is required.** Usually, teachers can be prepared for their teaching courses in the next few years. Planning the courses is conducive to recording teaching videos. It is convenient for teachers to record the whole educational video of a subject;
- **Awareness of teaching is one of our academic achievements.** Most teachers agree that teaching is an academic achievement equivalent to research accomplishment. Therefore, achievements are critical for teachers in college. Paying attention to the learning effects of students is important for college teachers;
- **Actively participate in teaching workshops or communities.** Through academic information exchanges in communities or workshops, teachers can obtain assistance and the latest information on educational training. It also creates opportunities for academic cooperation with teachers on campus. In the teaching community, information can be obtained, such as the application of the metaverse in education;
- **Sharing the recorded teaching materials.** Sharing and helping each other increase the influence of educational videos. Self-made teaching videos can be provided on free platforms such as YouTube. Virtual interaction with talented students throughout the world is possible;
- **Publishing teaching results on YouTube.** Uploading videos on YouTube is a type of publication, and the influence of YouTube is greater than that of journals or conference papers. The public release provides feedback on teaching achievements through discussions with viewers;
- **The publishing platform for reviews.** Submission of journal or conference papers requires rigorous peer review. Equivalently, teaching videos on YouTube need to pass a strict YouTube review process. Furthermore, students can become reviewers who provide valuable feedback;
- **Digitization preserves teaching records.** Many teachers have accumulated a large amount of teaching output. If the teaching materials can be organized and recorded into digital files, they are more conducive to inheritance, promotion, and preservation. One of the advantages of digitization is that it improves the efficiency of teaching;
- **When the going gets tough, the tough get going.** The production of teaching videos requires time and energy. It is difficult to achieve successful results without extraordinary perseverance. It is criticized sometimes for keeping free instructional videos on YouTube;
- **The traditional teaching mode still needs to be preserved.** Although the teaching mode can be changed through the recording of teaching videos, the traditional face-to-face teaching mode is still needed as communication between teachers and students is important;
- **Try to do all the work independently.** Teaching is a long-term career. It is difficult to maintain a studio team to record teaching videos for a long time. Therefore, teachers need to train themselves to become screenwriters, directors, and video editors. Then, recording teaching videos may last longer;

- **Writing course handouts.** In addition to recording teaching videos, teachers need to provide lecture notes for students' reference. Lecture notes are uploaded next to the corresponding teaching video so that students can easily click on them for reference;
- **Enjoy yourself.** Recording instructional videos is a difficult task. If the teachers enjoy recording teaching videos, they can continue for a long time.

3. Questionnaire Survey

An online questionnaire survey was conducted to collect data to understand how satisfied students were. The questionnaire was distributed to students in the engineering mathematics course. The questionnaire was created on a Likert 5-point scale, as shown in Tables 1 and 2. Questionnaires with full responses were included in the analysis.

Table 1. The score for each option.

Option	Score
Strongly Disagree	1
Disagree	2
Neither Agree nor Disagree	3
Agree	4
Strongly Agree	5

Table 2. Interpreted students' responses based on scores.

Interval	Students Responses
$1.00 \leq x < 1.80$ [a]	Very Bad
$1.80 \leq x < 2.60$	Bad
$2.60 \leq x < 3.40$	Neutral
$3.40 \leq x < 4.20$	Good
$4.20 \leq x \leq 5.00$	Very Good

[a] x = Scores of each indicator.

Based on the results of the 26 students' responses to the questionnaire, the score of each indicator was calculated as follows. The students' satisfaction with teaching videos scored 4.81 on average. Most students favored the quality of the engineering mathematics materials in the educational videos. The quality of the learning videos was evaluated as very good (Table 3).

Table 3. Students' responses to the developed teaching videos.

Indicator	Score	Response Category
The teaching materials developed by the teacher can inspire my interest in learning	4.77	Very Good
The recorded digital video provided by the teacher helps me adjust my learning progress	4.86	Very Good
Average	4.81	Very Good

4. Conclusions

Educational videos allow students to view on-demand materials repeatedly and learn at their own pace. Furthermore, videos on YouTube can be integrated to provide targeted information and enrich the learning environment for students. In this article, tips for creating an effective video on YouTube are provided to help record and integrate a video on YouTube. It is helpful for teachers to be interested in photography and have fundamental photographic concepts. It is recommended to understand the golden ratio of contents and the ten principles of art. Teachers are encouraged to train themselves to become screenwriters, directors, and video editors. Then, recorded teaching videos can last longer. Independent recording is recommended. Creating educational videos can go on

as long as teachers enjoy the process. However, it is difficult to obtain successful results without extraordinary perseverance. The questionnaire survey result shows that students' responses to the teaching videos were excellent, with an average score of 4.81. Quality and supplementary materials are important in educational videos.

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Using YouTube as an Effective Educational Tool to Improve Engineering Mathematics Teaching during the COVID-19 Pandemic

John C.-C. Lu

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Proceeding Paper

Using YouTube as an Effective Educational Tool to Improve Engineering Mathematics Teaching during the COVID-19 Pandemic †

John C.-C. Lu

Department of Civil Engineering, Chung Hua University, Hsinchu 30012, Taiwan; cclu@chu.edu.tw

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Abstract: An investigation and assessment of virtual learning in engineering mathematics during the COVID-19 pandemic were explored in this study. The result showed that the media platform was an especially useful technology for students to create, share, learn, and interact with others. YouTube, a free media-sharing website, has proved to be an effective educational tool to add a new dimension to education in increasing student engagement, motivation, understanding, and achievement. Thus, students' learning models on the OpenCourseWare YouTube channel were researched to investigate how virtual activities in e-learning of engineering mathematics during coronavirus confinement were implemented and describe how YouTube was used for teaching engineering mathematics by engaging students in mathematical problem-solving.

Keywords: COVID-19; engineering mathematics; YouTube channel; online learning

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1. Introduction

Improving teaching effectiveness has been tried continuously to help students engage more in learning. Therefore, a series of research related to engineering mathematics has been carried out with continuous funding from the Ministry of Education in Taiwan. The above efforts are aimed at attracting students to study engineering mathematics, and this also helps the author to improve teaching. The efforts include (1) integrating key points of engineering mathematics into multimedia teaching materials, (2) creating an appropriate environment for self-learning, (3) providing learning opportunities for students and enhancing comprehension ability by analogy, (4) constructing unit-themed learning materials, and (5) making an environment suitable for action learning. These efforts are especially critical for the conversion of in-person courses into virtual courses during the COVID-19 pandemic.

Paschal, Pacho, and Adewoyin [1] found effective teaching methods for higher educational institutions during the COVID-19 pandemic in Africa through empirical research. Simamora et al. [2] displayed the lecturer's perspectives during the COVID-19 pandemic in higher education and concluded that there was a need to continue exploring alternative learning environments to ensure learning with an effective, efficient, easy-to-access, and high-quality knowledge dissemination process. Marsudi, Lestari, and Hidayati [3] investigated the improvement in mathematics learning achievements of students after using YouTube as a learning media during the COVID-19 pandemic. They observed the impact of the interactive learning model and orientation of mathematics material on conceptual comprehension ability. Antón-Sancho and Sánchez-Calvo [4] recommended increasing the specific training for professors in the pedagogical usage of information and communication technologies addressing the specific knowledge in each area. Kanetaki et al. [5] identified variables that impacted student performance in the educational process disorientation due to the COVID-19 pandemic and concluded that innovative teaching improved students'

spatial conceptions. DeCoito and Estaiteyeh [6] revealed that online teaching was viewed negatively by most teachers in terms of student engagement and outcomes. Febrianto, Mas'udah, and Megasari [7] focused on determining the online learning process and the associated obstacles experienced by students. Their investigation showed the importance of the availability of supporting facilities, infrastructure, and facilitated internet access. Shahroury [8] demonstrated that the use of the flipped classroom strategy helped overcome the challenges associated with e-learning and maintain overall performance. The investigation of Beruin [9] revealed a generally unfavorable and unenthusiastic view of online learning during the COVID-19 pandemic. George [10] presented effective teaching and examination strategies that can be utilized for undergraduate learning courses during COVID-19 restrictions. Karasneh et al. [11] recommended that training programs and interdepartmental communication strategies be implemented and use fewer platforms to provide an efficient online learning experience. Libasin et al. [12] concluded that students and lecturers worked together to ensure similar learning outcomes before the pandemic. The work of Patalinghug and Patalinghug [13] displayed that using YouTube as a web-based instructional tool improved students' sociability, grades, learning motivation, and curriculum delivery through utilizing technology-enabled learning. Revelo-Rosero et al. [14] highlighted digital tools and resources available on the web to improve the teaching–learning process inside and outside the classroom. Abubakar and Muhammed [15] provided a rational literature investigation and analysis of the education teachers' pedagogy and YouTube video technology. There have been many related investigations about effective educational tools to improve teaching during the COVID-19 pandemic.

The series of videos on engineering mathematics on YouTube recorded by the author has helped many students learn well on engineering mathematics. Three representative students sent the appreciated messages from 2020 to 2022 on YouTube as follows.

- "Thank you so much, Teacher. You have helped me a lot. I cannot express how grateful I am right now. Thank you so much. Please stay safe and take care."
- "Thank you for your contribution, since mathematics is a universal language, I will always understand. Good video! Greetings from Mexico."
- "You may not believe me but I'm a Spanish speaker and I only know around 7 words in Chinese but it was so clear that I understand what you explain. Thank you so much!"

In this study, the ideas and keys are suggested to establishing a YouTube engineering mathematics teaching channel for readers' reference.

2. Creating Teaching Materials

There have been 39 teaching research projects implemented by the author since 2003, who had a strong interest in multimedia teaching and the integration of digital technology into teaching. Each project was focused on the research and development of innovative teaching materials. The research projects supported by the Ministry of Education in the past five years are shown in Table 1. All teaching materials have been uploaded on YouTube for interested students to use for free. The established OpenCourseWare on YouTube was applied to teaching and learning engineering mathematics during the COVID-19 pandemic. The goals of the projects are as follows.

- Studying according to their own pace
- Making teaching materials more interesting
- Helping students pass various exams
- Improving students' concentration on the study

- Triggering learning motivation
- Solidifying abstract ideas
- Enhancing memory and impression
- Shortening learning time
- Making teaching activities lively and funny
- Expanding information content can satisfy students' thirst for knowledge

Table 1. Projects supported by the Ministry of Education in 2018–2022.

Year	Project Title
2018	Study on the Establishment and Application of Teaching and Problem-Solving Handouts/Videos of the OpenCourseWare "Engineering Mathematics"
2019	Study on Case Study of the Application of OpenCourseWare "Engineering Mathematics"
2020	Study on the Design of Adding Interactive Tests to the Online Video of the OpenCourseWare "Engineering Mathematics"
2021	Study on the Frequently Asked Questions and Its Answers of OpenCourseWare "Engineering Mathematics"
2022	Evaluation of Key Points of OpenCourseWare "Engineering Mathematics" Using Animation Methods

The current research is focused on the animation presentation of the key knowledge of engineering mathematics. All the efforts are conducive to the implementation of student-centered pedagogy, question-and-answer pedagogy, technology-integrated pedagogy, problem-based pedagogy, design thinking pedagogy, and self-study tutoring. There is much interesting information displayed on YouTube. Instructors can improve teaching based on feedback in the detailed message. Figure 1 presents the welcome page of instructional YouTube developed by the author. Figure 2 shows that there were currently 3627 students subscribed to the educational channel. In 28 days, the YouTube channel had 12,899 accumulated views with 3619 non-repetitive audiences (Figures 3 and 4). Figure 5 presents the ordinary differential equation problem-solving process on YouTube, and the application of ordinary differential equations to structural mechanics is presented in Figure 6. Students could self-assess their learning effectiveness through online quizzes in H5P as displayed in Figure 7. The key points of engineering mathematics are presented by animation as shown in Figure 8. The project facilitated online learning of engineering mathematics while maintaining the quality of teaching.

Figure 1. Welcome page for browsing and Q&A (感謝瀏覽, 歡迎提問): YouTube instructional videos developed by the author at Chung Hua University (中華大學).

Figure 2. Channel dashboard (頻道資訊主頁): 3627 students subscribed to the engineering mathematics YouTube channel.

Figure 3. Channel data analysis (頻道數據分析): 12,899 views in the latest 28 days.

Figure 4. Channel data analysis (頻道數據分析): 3619 non-repetitive audiences in the latest 28 days.

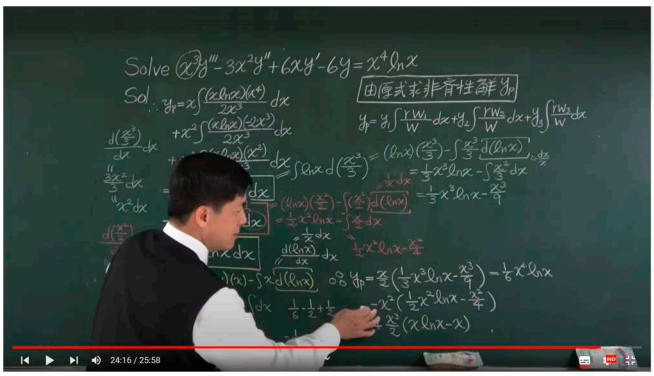

Figure 5. Problem-solving process of ordinary differential equation displaced on YouTube.

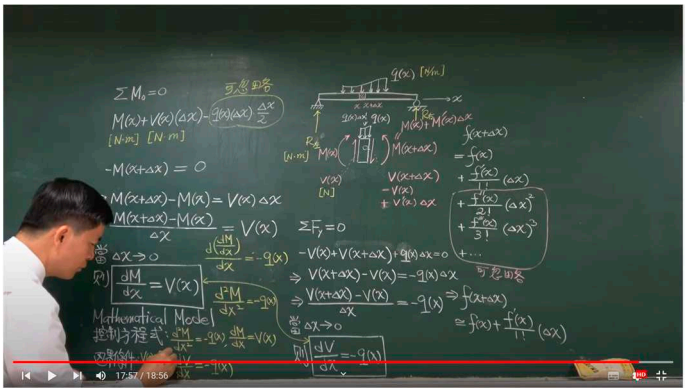

Figure 6. Application of ordinary differential equation on structural mechanics.

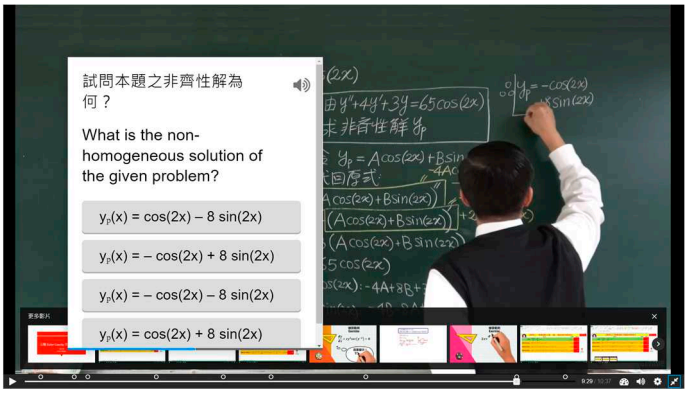

Figure 7. Self-assessment of learning effectiveness through online quizzes.

Figure 8. Key points of engineering mathematics are presented by animation.

3. Questionnaire Survey

An online questionnaire survey was conducted on the effectiveness of teaching videos with Google Forms. In total, 77 students from the courses of engineering mathematics in 2020–2022 participated in the survey. The descriptive analysis result showed that planning of learning scored 4.62 on a scale of 5. Thus, the recorded teaching videos on YouTube were effective during the COVID-19 pandemic (Table 2). The scores obtained for each indicator were interpreted based on the criteria of Table 3. The students' responses to the teaching videos are displayed in Table 4. The average score was 4.62, which showed student satisfaction. Most students liked the quality of the engineering mathematics materials in the educational videos, which implies that the quality of the learning videos was satisfactory, and the videos were helpful in online learning during the epidemic.

Table 2. Score on the Likert scale of the questionnaire.

Option	Score
Strongly Disagree	1
Disagree	2
Neither Agree nor Disagree	3
Agree	4
Strongly Agree	5

Table 3. Interpreted students' responses based on scores.

Interval	Students Responses
$1.00 \leq x < 1.80$ [a]	Very Bad
$1.80 \leq x < 2.60$	Bad
$2.60 \leq x < 3.40$	Neutral
$3.40 \leq x < 4.20$	Good
$4.20 \leq x \leq 5.00$	Very Good

[a] x = Scores of each indicator.

Table 4. Students' responses to the developed teaching videos in 2020–2022.

Indicator	Score	Response Category
The teaching materials developed by the teacher can inspire my interest in learning	4.59	Very Good
The recorded digital video provided by the teacher helps me adjust my learning progress	4.65	Very Good
Average	4.62	Very Good

4. Conclusions

Based on the findings in this research, the following conclusions are drawn.

There were 39 teaching research projects implemented by the author since 2003. Each project focused on the development of innovative teaching materials. All of the teaching materials have been uploaded on YouTube for students to use for free. The results of the online survey with 77 students in 2020−2022 showed that students' responses to the developed teaching videos scored 4.62 on a scale of 5, which was very good. Students studied according to their own pace on YouTube. Furthermore, teaching materials made the course more interesting and maintained the quality of instruction. The developed teaching videos integrated the key points of engineering mathematics into multimedia teaching materials and built a suitable environment for active learning. All the efforts were conducive to the implementation of student-centered pedagogy, question-and-answer pedagogy, technology-integrated pedagogy, problem-based pedagogy, design thinking pedagogy, and self-study tutoring.

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