國立臺灣師範大學資訊教育研究所

碩士論文

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資訊科技融入中小學數學科教學之
系統性文獻分析：2000 年至 2012 年

Information and Computer Technology in K-12 Mathematics Classrooms: A Systematic Review of the Literature Published between 2000 and 2012

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摘要

資訊科技融入中小學數學科教學之系統性文獻分析：2000 年至 2012 年

黃郁雯

本研究使用系統性文獻分析法，彙整 2000 年至 2012 年期間發表於英文期刊之資訊科技融入中小學數學科教學之文獻共 79 篇，以探討資訊科技工具運用於數學科課堂教學之概況。研究者首先選定所欲搜尋之五個電子資料庫，並訂定搜尋字串，繼而擬定文獻篩選準則以選取符合本研究需求之文獻，接著使用資料萃取表，針對篩選所得之文獻萃取各篇文獻中與本研究相關之重要資料，最後進行萃取所得資料之彙整與分析。研究結果顯示，數學科之五大教學主題（數與運算、代數、幾何、測量、及資料分析與機率）皆可見資訊科技融入教學之案例，其中以「數與運算」（28.6%）、「幾何」（27.4%）、和「代數」（24.5%）之個案最為常見。在數學科所使用之資訊科技硬體設備方面，使用最多的是桌上型電腦（68.5%），次為圖形計算機（11.2%）及電子白板（10.1%），其他尚有使用筆記型電腦、平板電腦、及掌上型電腦之零星個案；至於軟體工具方面，數學科教學軟體以虛擬教具（19.2%）、動態幾何軟體（15.6%），以及指導式 CAI 軟體（15.6%）為主，其次為遊戲式 CAI 軟體（8.4%）以及搭配硬體設備使用之圖形計算機內建軟體（10.9%）、辦公室套裝軟體（8.4%）、及電子白板之內建軟體（6%）。資訊科技工具之特性中，則以「互動性」與「視覺化」最有利於學習。本研究另亦發現，以資訊科技工具為基礎所設計之學習活動可培養記憶、理解、應用、與評鑑等不同層次之認知能力，其中尤以利用資訊科技工具促進記憶層次之「回憶」以及理解層次之「舉例」與「推論」能力為主，其次則用於培養應用層次之「執行」與理解層次之「詮釋」能力，至於分析與評鑑層次則較為少見，創造層次更是付諸闕如。本研究結果應可作為中小學數學教師實施資訊科技融入教學之具體指引。

關鍵詞：資訊科技融入教學、系統性文獻分析、中小學數學科教學

Abstract

Information and Computer Technology in K-12 Mathematics Classrooms: A Systematic Review of the Literature Published between 2000 and 2012

By

Yu-Wen Huang

The study used systematic review of research method. .The purpose of this research is to compile the literature published between 2000 and 2012 about the information and computer teachnology in K-12 mathematics classroom. It is a total of 79 literatures. The study fous on overview the information technology integrate into K-12 mathematics classroom.The first the researcher select desired search of five electronic databases, and set the search string, and then develop screening criteria to select the line with the literature of the research literature needs. And then use the data extraction tables for the extraction of the literature with important information. The final compilation and analysis of information obtained in the extraction. The results showed that the five teaching units (Number & Operations, Algebra, Geometry, Measurement, and Data Analysis & Probability) have case of information technology into teaching, in which the "Number & Operations" (28.6%), the "Geometry" (27.4%), and "Algebra" (24.5%) of the most common. In the hardware that the main types is desktop computers (68.5%), followed by graphics calculators (11.2%), and electronic whiteboard (10.1%), others have a little are like a notebook computer, tablet PC, handheld computers. And the software that the main types are the virtual manipulatives, dynamic geometry software (15.6 percent), and CAI software (15.6 percent), followed by the game software (8.4%), and graphics calculators the built-in software (10.9 percent), office software (8.4%), and whiteboard software the built-in (6%). The characteristics of the information technology tool are interactivity and visualization that the most to help students learning. The study also found that the integrating information technology into instruction can foster students's cognitive abilities such as remember、understand、apply and evaluate. Especially in foster the main abilities is recalling of remember, exemplifying and inferring of understand, the next foster the executing of apply and interpreting of understand. The the analyze is rare and without the create. The results of this study should be used K-12 mathematics teachers to implement specific guidelines for integrating information technology into teaching.

Keywords: Integrating information technology into instruction, Systematic review, K-12 mathematics teaching.

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目錄

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第一章　緒論

近年來，由於教育理念的改變，各國紛紛致力於推廣資訊科技融入教學，試圖藉由科技工具的使用，為學生帶來不一樣的學習體驗與提供更多學習機會，以提升學習成效。本章說明本研究之研究背景與目的。

第一節　研究背景

過去數十年間，資訊科技工具融入中小學教學之現象日益普及，相關研究結果散見國內、外媒體。舉例而言，蔡欣嘉（2006）蒐集 2001 到 2006 年間之 39 項研究，發現其中絕大多數（93%）之研究結果支持資訊科技融入教學能提升學生的學習成效，優於傳統教學方式；蕭英勵（2009）蒐集台灣地區 2001 至 2009 年之學位論文，以探討中小學資訊科技融入教學之研究趨勢與發展，其研究結果顯示，教師運用資訊科技輔助教學，可提升學生學習抽象概念之成效，並且對於學生日後運用資訊科技於學習也有正面影響；王珀芬（2010）收集 2001 年至 2008 年期間資訊科技融入教學之學位論文進行後設分析，也發現資訊科技對於中小學生之學習成就與學習態度均有正面影響。此外，Harrison 等人（2002）研究 1999 年至 2002 年期間英國各地區小學實施資訊科技融入教學的狀況，再次確認了資訊科技的輔助可為學生的學習帶來正向效益，而 Andrews 等人（2002）進行系統性文獻分析，亦發現網路科技能提升五歲至十六歲學生之學習成效。

中小學的所有學科中，數學科一向備受重視，因為它不僅是重要的考試科目之一，數學知識亦是日常生活與職場中必備的基本能力。然而，數學亦是公認較難學習的學科。雖然上述研究均顯示數學教師不斷追求創新的教學方式，試圖提升學生的學習興趣與學習效果，但依然有許多學生遭遇學習困難。

Santos-Trigo（2004）指出，數學科教學應讓學生主動思考、探索、應用習得之知識與技能、以自己的方式呈現解題想法。當學生透過科技工具的輔助來建構

各種不同的數學表徵、提出自己的想法、與他人進行討論時，就有機會重新思考、建構或修正習得之數學知識與技能。美國數學教師協會（National Council of Teachers of Mathematics，簡稱 NCTM，1983）建議中小學教師於講授數學概念與培養學生之數學技能時，應將科技工具融入教學中。該協會於 2000 年所出版之「學校數學原則與標準」（Principles and Standards for School Mathematics）中，再次強調數學教育使用科技工具的重要性，並表示科技工具不僅有助於提升學生學習數學之成效，更可有效改變數學的教學內容（NCTM, 2000）。另有許多研究顯示資訊科技融入教學使學生對數學的興趣與學習成效有幫助（楊立德，2007；黃美齡，2009；李曉萍，2010）。

為使資訊科技融入數學科教學帶來最佳效益，教師們在進行資訊科技融入教學前，對於適用於數學科教學之軟、硬體設備、各類科技工具所具有之特性與功能、以及如何使用科技工具設計最有效之學習活動等等，應有足夠認識。因此，本研究試圖探討近年來資訊科技融入中小學數學科教學之概況，以提供數學教師具體之教學指引與參考。

第二節　研究目的

本研究旨在透過系統性文獻分析法（Systematic Review），綜觀 2000 年至 2012 年期間與資訊科技融入中小學數學科教學相關之英文期刊論文，檢視資訊科技融入數學科教學之實施方式。具體而言，本研究試圖針對以下各項議題進行文獻資料之彙整與分析：

1. 資訊科技工具融入數學科教學之概況為何？
2. 資訊科技工具具有哪些有助於數學學習之特性？
3. 資訊科技工具對於培養學生認知能力之影響為何？

第二章　文獻探討

本章針對研究主題進行相關文獻之整理與探討，一共分為五節，第一節說明資訊科技融入教學之意涵；第二節說明前人針對資訊科技融入數學科教學進行與本研究類似之綜合性研究所採用之方法與研究結果；第三節介紹數學科教學中較具知名度之科技工具；第四節說明布魯姆（Bloom）之認知領域教育目標分類；第五節則描述系統性文獻分析法（Systemic Review）之發展與實施步驟。

第一節　　資訊科技融入教學

本節說明資訊科技融入教學之意涵。

一、資訊科技融入教學之意涵

美國國家教育統計中心（National Center for Education Statistics, NCES）於2002年出版的Technology in Schools Suggestions, Tools, and Guidelines for Assessing Technology in Elementary and Secondary Education 中，將「科技融入」（Technology integration）定義為：「科技融入教學乃是整合科技資源，並且將之實際地應用於學校的日常工作與管理中」。另有學者指出，資訊科技融入教學是教師運用資訊科技於課堂教學中和課後活動上，用來培養學生的「運用科技與資訊」能力與「主動探索與研究」精神，進而使學生能夠「獨立思考與解決問題」，並且完成「生涯規劃與終身學習」（張國恩，1999）。徐新逸（2003）則將資訊融入教學之定義分為狹義與廣義兩種，前者為資訊科技的技術應用，後者則為應用科學方式進行系統化教學設計，以達到學習目標，並提供學習者更有意義的學習歷程，進而提昇教師教學與學生學習的成效。何榮桂（2002）則認為資訊科技融入教學是教師依教材內容性質來選擇適當的資訊科技進行教學，同時能增進學生的資訊相關知能和學習領域能力之成長。

綜合上述各專家學者之看法，本研究定義資訊科技融入教學為：配合課程、

教材以及教學之需求，將資訊科技工具運用於教學前之課程準備或教材設計、課堂教學中學習活動、或教學後之複習與評量活動等，其目的在於以學生為學習中心，使資訊科技成為輔助學生學習之工具，進而提升教師之教學成效與學生之學習成效。

第二節　資訊科技融入數學科教學之整合性研究

本研究的目的在於採用系統文獻分析法，以綜觀近十年資訊科技融入數學科教學之概況。過去亦有學者做過類似的整合性研究，其研究方法與結果詳列於表 2-1。

表 2- 1 資訊科技融入數學科教學之綜合性相關研究

研究者（年分）	研究對象	研究方法	研究結果
Hembree & Dessart (1986)	1. 中小學學生（Grades K-12）。 2.學生使用圖形計算機進行學習。 3.1969 年到 1983 年期間出版之期刊文獻與碩、博論文或其他來源。	1.探討圖形計算機對學生之數學學習成就與態度之影響。 2.使用後設分析法。 3.分析 79 篇文獻。	1.圖形計算機搭配傳統教學可改善中小學(除了四年級學生)之中成就學生的基本運算與解題能力。 2.圖形計算機對四年級中成就學生之基本能力的提升有適得其反的效果。 3.學生於測驗時使用圖形計算機可提升其測驗分數，特別是低成就與高成就學生於解題的時候。

表 2-1 資訊科技融入數學科教學之綜合性相關研究（續）

研究者（年分）	研究對象	研究方法	研究結果
Hembree & Dessart (1986)			4.圖形計算機使學生有較好的數學學習態度與自我概念。
Ellington (2003)	1.中小學學生（Grades K-12）。 2.1983 年 1 月到 2002 年5月出版之期刊文獻與碩、博論文或其他來源。	1. 探討計算機（Calculators）對學生之數學學習成就與態度之影響。 2.使用後設分析法。 3.分析 54 篇文獻。	1.計算機可改善學生於數學之運算與解題技能。 2.學生使用計算機有較好的學習數學之態度。
Christmann & Badgett, (2003)	1.國小學生（Grades K-6） 2.1969年到1998年出版之出版之期刊文獻。	1.探討傳統教學有無 CAI 軟體輔助對學生數學之學習成就影響。 2.使用後設分析法。 3.分析 39 篇文獻。	1.CAI 軟體對國小學生之數學學習成就有正向影響。
Ellington (2006)	1.中學至大學第一年之學生。 2.學生使用圖形計算機進行學習。	1.探討圖形計算機對學生發展數學技能（程序性與概念性能力）之影響。 2.使用後設分析法。 3.分析 42 篇文獻。	1.當圖形計算機融入數學教學而無融入測驗時，有助於學生發展必要技能以理解概念。 2.當圖形計算機融入數學教學且融入測驗時，有助於改善學生的程序性與概念性之能力。
Li & Ma (2008)	1.中小學學生（Grades K-12）。 2.1990年到2006年出版之期刊文獻與研討會研究報告。	1.探討資訊科技融入中小學數學教學之情況。 2.使用後設分析法。 3.分析 39 篇文獻。	1.年級與性別是影響資訊科技融入數學科教學成效之最重要的因素。

表 2-1 資訊科技融入數學科教學之綜合性相關研究（續）

研究者（年分）	研究對象	研究方法	研究結果
Li & Ma (2008)			(1)提升中學生之數學學習成較國小生來的顯著。 (2)國小女生使用資訊科技進行學習其學習成就改善最大。 2.資訊科技搭配傳統教學或是建構式教學，對學生之數學學習成是無顯著影響。 3.資訊科技之種類學生的數學學習是無影響的。
Li & Ma (2010)	1.中小學學生（Grades K-12）。 2.1990年到2006年出版之期刊文獻與碩博士論文。	1. 探討電腦科技（Computer technology）對中小學之數學學習成就之影響。 2.使用後設分析法。 3.分析 46 篇文獻 。	1.電腦科技對中小學學生之數學成就有顯著之正向影響。 2.電腦科技對特殊學生之數學成就影響較一般學生來的大。 3.電腦科技結合建構式教學比傳統教學對學生數學成就之影響大。
Cheung & Slavin (2013)	1.中小學學生（Grades K-12）。 2.1960年到2011年期間出版之期刊文獻與未出版文獻(研討會與碩論)。	1.檢視教育科技運用於數學科教學之影響。 2.使用後設分析法。 3.分析 74 篇文獻	1.教育科技軟體對數學成就有正向影響。而 CAI 軟體影響最大。

由表 2-1 可知，過去整合性相關研究大多是使用後設分析法來探討或檢視資訊科技融入數學科對學生之學習成就與學習態度的影響，或是探討哪些因素會影響資訊科技融入數學科教學之成效。本研究與這些研究不同之處，則是使用系統性文獻分析法來探討資訊科技工具融入中小學數學科教學所能培養或促進之學生認知發展，以利數學教師參考採用於其教學之中。

第三節　數學科教學較常見之資訊科技工具

在數學科教學中，較常見之資訊科技工具除了各種類型之電腦外，另有虛擬教具、動態幾何軟體、圖形計算器、電子白板、電腦輔助教學軟體等五類。為方便讀者了解本研究在第四章所呈現之文獻分析內容，此節詳細說明上述五類工具之主要功能。

一、虛擬教具

顧名思義，虛擬教具乃是將實體教具虛擬化，以電腦上的動態物件來取代實體教具。它們可以是放置在網路上或是單機版的應用軟體。使用者可使用滑鼠對電腦螢幕上具有互動性的視覺化動態物件，進行類似實體教具的操作，像是旋轉、移動等，從中建構數學知識。它們與實體教具通常有著類似的名稱（Moyer et al, 2002; Moyer, Salkind & Bolyard, 2008; Bouck & Flanagan, 2010）。

常見的虛擬教具來源有美國國家虛擬教具庫（National Library of Virtual Manipulatives，NLVM）、美國全國數學教師協會（National Council of Teachers of Mathematics，NCTM）之網站教材資源、NCTM Illuminations 以及單機版的應用軟體等。其中美國國家虛擬教具庫所提供之虛擬教具最常被採用。此教具庫係由美國猶他州立大學（Utah State University）所開發，收集了大量的虛擬教具與教學及資源。該網站將教學內容分為數與運算、代數、幾何、測量及資料分析與機率等五大主題，提供各種 Java Applet 開發的數學工具，讓教師自由取用（NLVM, 1999）。

Yuan（2005）歸納了虛擬教之特性：(1) 可變性：學習者可針對某一物件的某一部分塗顏色、增減某一物件之數量等；(2) 無限量供應性：虛擬教具可解決課堂上實體教具不足的問題，也能解決分發教具與整理教具耗費時間的問題，虛擬教具之整理時十分方便，例如使用者只需點選如資源回收筒的圖示，即可立即清除畫面上的教具；(3) 多重表徵：虛擬教具可同時呈現不同的數學表徵，例如：圖形、符號或是數值，此可強化表徵間之連結。

Sayeski（2008）則整理了網站式虛擬教具之六項功能：(1) 指導說明（Instruction）：描述如何操作虛擬教具，並說明問題解決步驟；(2) 引導問題（Guiding Questions）：當學習者遭遇困難時，提供引導；(3) 解釋（Explanations）：學生有疑惑時可按下「解釋」按鈕，請求系統提供說明。(4) 立即回饋（Immediate Feedback）：針對學習者的回答，立即提供回饋；(5) 多重練習機會（Multiple Practice Opportunities）：學習者可自由選擇不同難易度的題目進行練習；(6) 分數報告（Score Reports）：學習者可列印分數報告作為學習紀錄。

江玉玲（2010）也針對虛擬教具彙整其特性如下：(1) 互動性（Interactivity）：學生可以像操作實體教具一樣，透過滑鼠進行滑動、旋轉或是翻轉；(2) 可得性（Availability）：虛擬教具大多可從網路上免費下載使用；(3) 理解性（Comprehensibility）：虛擬教具可幫助學生了解學習內容；(4) 連結性（Interconnectivity）：虛擬教具可動態呈現視覺物件、符號以及算式，亦可被操作與移動，使得視覺、操作以及符號表徵可被緊密地結合；(5) 回饋性（Feedback）：虛擬教具針對學習者的學習情況提供立即性回饋，引發其思考、驗證及澄清錯誤觀念；(6) 趣味性（Interestingness）：虛擬教具可引起學生的好奇心，進而提升其學習興趣與動機，使其更加專心於學習活動；(7) 效率性（Efficiency）：虛擬教具可不斷地被重複使用，學生也不需等待輪流使用與花時間於整理教具；(8) 步驟性（Step by Step）：於學習過程中，給予步驟性的引導來幫助學生釐清概念。

由上述可知，虛擬教具主要的功能包括：(1)呈現數學之多重表徵，(2)給予學習者回饋、引導與說明，(3)提供學習者多重練習，(4)可重複使用以節省整理教具

與學生輪流使用教具的時間。

二、動態幾何軟體

動態幾何（Dynamic Geometry）軟體的發展，首先有 Geometry Supposer（1985）軟體，接著有 Cabri Geometry（1988）、Geometer's Sketchpad（1992）、Cabri II Geometry （1994）、Eulid （1994）、Java Sketchpad（1997），直到 Cabri 3D 與 GeoGebra（2001）等等。這些軟體的版本不斷更新且功能持續地增強。

動態幾何軟體提供基本的幾何作圖工具，具備尺規作圖、圖形變異或動態連續變換、記錄整個作圖過程以及於網路建立檔案與展示等特質。某些動態幾何軟體還包含代數內容，提供繪製與導出函數精確圖形之功能，且具有可操作之特性，讓學習者易於探討各種幾何或函數圖形（林保平，2004），以下介紹常見的動態幾何軟體（姚念廷，2009）：

1. GSP（The Geometer's Sketchpad）

GSP 是 The Geometer’s SketchPad 動態幾何軟體的簡稱，由美國 Swarthmore College 及 Key Curriculum Press 所開發出來的軟體。GSP 動態幾何軟體是一套在視窗環境下將物件導向動態連結的幾何軟體，其工具有平移、對稱、旋轉及縮放等四種功能物件存在。其為一個尺規作圖功能強大的平面幾何構圖電腦輔助教學軟體，可精確地構造動態幾何。學生經由動態幾何圖形的變換及度量來描述他們所發現的一些幾何關係，增強開放式的猜測與研究，適合處理一些動態幾何圖形的模擬實驗與觀察。可對結構性作圖作巨集建構、文字說明，形成簡易操作按鈕。

2. GeoGebra

GeoGebra 是 Geo+Gebra，表示其為結合幾何（Geometry）與代數（Algebra）之軟體。是一套由 Markus Hohenwarter 教授及一個國際程式設計團隊所共同開發之免費的數學繪圖軟體，其具有幾何、代數、微積分以及統計圖表的功能。透過不同的表徵呈現數學物件與表徵之動態連結，使學習者於此種環境下易於學習數學。當學習者於繪圖區繪製直線或是圓形，而代數視窗則會出現對應方程式。反

之，若是輸入方程式，繪圖區則會出現對應之圖形。

3. Cabri Geometry

Cabri Geometry 是法國人開發之幾何尺規作圖軟體，用於解析幾何、代數與物理的學習與教學。其操作介面具有動態變換、幾何量的測算、軌跡方法求解等功能，並且能快速地生成各種幾何圖形、平面曲線等，亦可轉成 Java 檔案將之置於網路上。

4. Cabri-3D

Cabri-3D 科技誕生於法國國家科學研究中心（CNRS）和法國格勒諾布爾的約瑟夫-希爾大學（Joseph Fourier University）。這是一套動態立體幾何軟體，其延續尺規作圖的方式，使用者能透過滑鼠來建構立體幾何圖形，從工具列之點選即可建構並操作一些立體的幾何物件。從功能表中可以看見正在操弄的立體幾何圖形產生屬性與視角的改變，且可在同一時間開啟多個觀看視窗與各種角度的透視圖像，藉由拖曳滑鼠右鍵調整立體視角的角度。

綜上所述，動態幾何軟體主要功能與特質為：

(1) 符合尺規作圖原理（Euclidean constructions）：

動態幾何軟體提供繪圖工具，為仿照直尺或圓規之作圖方法。使用者能快速且容易製作出精確的幾何圖形，例如：畫圓、圓弧、點、直線、平行線、垂直線還有角平分線等。同時，線與線、線與圓或是圓與圓之間會立即產生交點，運用這些基本的功能進行各種組合，就可以繪製出較為複雜的幾何圖形。

(2) 圖形可操作，具幾何變換功能：

動態幾何軟體工具可讓使用者在視窗內運用滑鼠依作圖時的定義來移動整體或部分圖形之位置或改變其形狀，也可運用軟體提供的幾何變換（Geometric Transformation）功能進行變換基準，例如：平移向量、旋轉角度、縮放比例及旋轉其中心等等（Rahim, 2002）。

(3) 提供解析幾何（Analytic Geometry）的座標系統：

動態幾何軟體能進行定點座標描點、求任意點的座標、距離長度、斜率等，也可畫出多種的函數圖形，例如：三角函數、多項式函數、指數函數以及對數函數等等。

(4) 動態連續變化及不變性：

動態幾何軟體能使圖形及數值做連續的變動，也就是當圖形或圖形中某一個構成元素被改變形狀、位置或是變換時，使改變的過程是漸進且連續性的，讓學生能透過觀察圖形連續變換之過程進而發現幾何圖形的不變性質（Invariant）（林保平，1997）。

(5) 同時具手動操作及自動化功能：

動態幾何軟體具有動態模擬（Animate）與拖曳（Dragging）功能，學生能透過動手操作控制速度，方便觀察、比較與臆測。因為手動操作不易精準，例如：重合圖形或疊合圖形，而電腦自動操作的按鈕，可使圖形自動校正，增加準確度（林保平，1995）

(6) 互動性、視覺化、情境化、數值化以及圖像與文字結合的多重表徵視窗環境：

動態幾何軟體能使圖形或函數式的參數產生變動，進而使函數式與圖形作相對應的變動，此時，其座標也會改變。軟體的視窗中可同時呈現（1）文字模式（Text mode）：問題的情境；（2）數值模式（Numerical mode）：探索參數、函數、測量值等各種的變化；（3）圖形模式（Graphical mode）：對應數值會隨圖形變化而有所變動。各種模式之間是動態連結的，也就是當文字模式的數值改變的時候，其相對應的數值或是圖形模式會立即地更動（謝哲仁，2001）。

三、圖形計算器

圖形計算器（Graphing calculator）是指一種能夠畫函數圖、解聯立方程組以及執行其它各種操作的手持計算器，大多數圖形計算器還可編寫程序。由於它們的螢幕很大，因此也能夠同時顯示多行文本。有一些圖形計算器甚至有彩色顯示

或三維作圖功能。由於，圖形計算器亦可編寫程式，故被用於製作電子遊戲。圖形計算器內建繪圖軟體，使用者可進行函數與幾何學繪圖、CAS 計算、試算表以及統計分析。

出產圖形計算器的公司為數不少，世界第一台圖形計算器 Fx-7000G 是由 CASIO 於 1985 年製造的，不久後惠普也推出 HP-28C，接著出產的款式有 HP-28S（1988）、HP-48SX（1990）、HP-48S（1991）等等。而惠普於 2006 年所推出的 HP 50g 還具有計算機代數系統（CAS）。德州儀器（Texas Instruments）則自 1990 年起開始生產圖形計算器，其中最老的型號為 TI-81，之後陸陸續續出產的有 TI-82 系列，TI-83 系列與 TI-84 Plus 等等。而 TI-89 和 TI-92 具有計算器代數系統（CAS）。

四、電子白板

電子白板是一個大型的觸控板，藉由連結電腦、投影機進行運作。其核心硬體包括一塊電子感應板（Electronic whiteboard）及感應器。電子感應板為觸控式螢幕，具有書寫的功能。而感應器通常是一支具有滑鼠功能的感應筆（Electronic stylus），當連續書寫時就有數位墨水（Digital ink）的功能。就外觀與功能上而言，互動電子白板與傳統白板（黑板）是無差異的，不過，其一旦與電腦或是投影機連結之後，電子白板可透過驅動其內建的軟體直接連上網際網路，以形成人機、人際多重且高度互動的教學體系（陳惠邦，2006）。

出產互動電子白板的公司不少，像是英國Promethean公司所生產ActivBoard、加拿大SMART科技公司所生產的SmartBoard、國內生產的IT-Board與iBoard，但所提供的基本功能大同小異，大多具有以下幾項功能（陳惠邦，2006、劉信宏，2013）：

1. 互動功能

電子白板為一個大型觸控螢幕，是顯示器也是輸入設備，使用者只需要用手指觸摸電子白板就可以自由地操控各種檔案或是應用程式，也可讓電腦與電子白板同步顯示同一個畫面。

2. 書寫功能

(1) 感應筆或手指可調整筆的粗細，並且可選擇不同的顏色，以方便註記且增加畫面豐富感。

(2) 具有板擦的功能，可於電子白板上任意地擦拭。

(3) 書寫後的資料可以被儲存、重複播放或是列印出來。

(4) 可使用並累積內建素材庫，除了電子白板本身內建的數學教學素材之外，使用者可新增或修改素材庫的內容，使得素材庫的資料越來越豐富。

3. 記錄教學歷程功能

使用者的操作過程、書寫的註記與筆跡皆可被擷取下來、錄製成圖片或影片，方便教師與學生於複習的時候使用。

4. 其他功能

例如：支援多媒體，可連結並運用網際網路，也可連結或是插入外部資源，像是圖片、影音及Flash等，而儲存的檔案也可匯出成PDF、HTML等格式，甚至可以直接E-mail。

(1) 在電子白板上可快速新增或刪除或切換頁面。

(2) 具有放大、聚光燈、螢幕遮罩等功能，不僅吸引學生的注意力也加強教學成效。

五、CAI 教學軟體

電腦輔助教學軟體（CAI）一詞源自教育科技之發展初期，用來泛指各種教學軟體，目前仍被廣泛使用。雖然其名稱不盡相同，但依據 CAI 教學軟體之功能可分為六類（Roblyer& Doering, 2010），各類教學軟體功能與特性之說明如下：

1. 反覆練習軟體（Drill and practice software functions）

這類軟體能讓學習者解決或回答問題，並且得到正確的回應。也就是提供例題給學習者練習，並針對學習者的答案是否正確給予回應。有些較高階的反覆練習軟體會依學習者答對題狀況，給予適當的題目難易度等級，學習者答對時，題

目的等級會由初階至高階;反之,若學生答錯時,題目的等級則會降至較為低階。而有些還能讓學習者瀏覽答錯的題目，由於無指定學習者，故可自由選擇其他等級，學生能看見題目等級之間的差異。反覆練習軟體之特徵為：

(1) 呈現讓學生做答的項目。

(2) 對於學生的正確答案給予回饋。

(3) 對於學習者之不正確答案予以說明。

2. 指導式軟體 （Tutorial Software）

此軟體扮演如教師般的角色，提供學生熟悉學習主題所需的，包括：摘要資料、註解、固定練習、回饋以及評量。指導式軟體之特徵為：

(1) 呈現一個完整的教學順序。

(2) 是完整的教學，而非補充教學。

(3) 包括反覆練習功能。

(4) 可以是直線式或分支式。

3. 模擬軟體（Simulation Software）

此軟體為電腦化的模擬實境系統，用以解釋與說明事物體系的運作過程。往往需要使用者自己設定使用序列，決定要進行的事項與順序。模擬軟體之特徵為：

(1) 模擬一個真實或假想的系統。

(2) 可以模擬物理現象（例如，成長），程序（例如，夾層），並假設情況（例如，股市）。

(3) 使用者可以看見他們自己行為之影響（Users can see the impact of their Actions）。

4. 遊戲式軟體（Instructional Games）

此軟體是在學習活動中加入遊戲規則以增進學習動機，通常透過練習或模擬的形式進行，具有遊戲規則、挑戰或是競爭要素、有趣或娛樂性的編排，此些要素引發學生習者內心與情感上的期待。遊戲式軟體之特徵為：

(1) 在有趣與娛樂性的情境下，給予學習者技能練習或解決問題的機會。具有遊戲規則。

(2) 讓學生在挑戰的情境下，競爭與取勝。

5. 問題解決軟體（Problem-Solving Software）

此軟體藉由解釋或練習，直接指導學習者問題解決中的步驟，或提供學習者解題機會，協助他們習得解題技巧。此軟體之特徵為：

(1) 工具幫助學生解題。

(2) 教學軟體環境讓喜歡面對挑戰的學生能創造解題方法以解決複雜的問題。

(3) 軟體中呈現的問題是為了幫助學習者發展解題技能的要素。

(4) 學習者有練習解決問題內容之機會。

6. 整合式學習系統（Integrated Learning Systems）

此軟體以「一次全包」的方式提供軟體工具，每一個整合式學習系統會提供各種教學技巧。除了結合反覆練習、個別指導、模擬、問題解決以及一些工具軟體，整合式學習系統亦可以保存每位學生作業及表現的詳細紀錄，使教師可以印出這些資料。整合式學習統之特徵為：

(1) 網路或線上系統教學。

(2) 提供完整的教學主題之課程。

(3) 監控與提供學生學習情形。

(4) 匯整學生、班級或學校之資料。

第四節　布魯姆認知領域教育目標分類

布魯姆（Benjamin S. Bloom）教育目標分類系統一直被廣泛地應用在教育上的課程、教學、評量和測驗編製上，因此，它所帶來的影響力可說極為深遠。由於本研究使用布魯姆認知分類修正版來分析資訊科技融入中小學數學科技教學

之學習活動，故將以下的說明重點放在修訂版上。

Anderson 與 Krathwohl 於2001年出版 A Taxonomy of Learning, Teaching and Assessing：A Revision of Bloom’s Educational Objectives 一書，針對舊版中的知識分類及認知層次，作了大幅修訂。修訂後的六個認知領域教育目標，從較低層次「記憶」到較高層次的「創造」，分別為記憶、理解、應用、分析、評鑑以及創造。如圖2-1所示，在這六個教育目標之下，一共有 19 個次類項目：記憶包含識別與回憶；理解包含詮釋、舉例、分類、摘要、推論、比較以及解釋；應用包含執行與實行；分析包含辨別、組織以及歸因；評鑑包含檢查與評論；創造包含產生、計畫以及製作。舊版本之知識分類及認知層次形成了一個「累積階層」（cumulative hierarchy），亦即前一類是次一類的基礎，而修訂版則是屬於「漸增複雜性階層」（increasing complexity hierarchy），亦即當層次越高時，其所包含的次類項目之複雜度也會越來越高（Krathwhol, 2002）。

Structure of the Cognitive Process Dimension of the Revised Taxonomy

1.0 Remember – Retrieving relevant knowledge from long-term memory.
- ***1.1 Recognizing***
- ***1.2 Recalling***

2.0 Understand – Determining the meaning of instructional messages, including oral, written, and graphic communication.
- ***2.1 Interpreting***
- ***2.2 Exemplifying***
- ***2.3 Classifying***
- ***2.4 Summarizing***
- ***2.5 Inferring***
- ***2.6 Comparing***
- ***2.7 Explaining***

3.0 Apply – Carrying out or using a procedure in a given situation.
- ***3.1 Executing***
- ***3.2 Implementing***

4.0 Analyze – Breaking material into its constituent parts and detecting how the parts relate to one another and to an overall structure or purpose.
- ***4.1 Differentiating***
- ***4.2 Organizing***
- ***4.3 Attributing***

5.0 Evaluate – Making judgments based on criteria and standards.
- ***5.1 Checking***
- ***5.2 Critiquing***

6.0 Create – Putting elements together to form a novel, coherent whole or make an original product.
- ***6.1 Generating***
- ***6.2 Planning***
- ***6.3 Producing***

圖 2- 1 認知領域教育目標之認知過程修訂版（Krathwohl, 2002）

以下簡述布魯姆認知領域教育目標修訂版之定義與內容（Krathwohl, 2002）：

1. 記憶（Remember）

記憶是指從長期記憶體提取相關知識，可分為識別和回憶。

(1) 識別（Recognizing）：學生搜尋長期記憶以找出與呈現之資訊一致或相近的知識。

【示例】下列哪一個圖形是七角形?

(2) 回憶（Recalling）：當提示（問題）出現時，學生從長期記憶中提取相關的知識。

【示例】請寫出圓面積公式：____________

2. 理解（Understand）

理解是從教學訊息，包含課堂上、書本中或電腦螢幕上的口語、書面與圖形訊息，從中創造意義，並且使舊經驗與新知識能做連結，可分為詮釋、舉例、分類、摘要、推論、比較以及解釋。

(1) 詮釋（Interpreting）：學生能將資訊從一種表達方式轉換至另一種方式，也就是不同的知識表徵之間的轉換。包含從圖畫表徵轉換至文字表徵；從文字表徵轉換到圖畫表徵；從數字表徵轉換至文字表徵；從文字表徵轉換至數字表徵等。

【示例】使用圖形表徵呈現分數符號表徵：「請用圓形圖表示分數 23/5」。

【示例】將文字敘述轉換到符號表達之代數方程式：請把以下文字描述以方程式表示「班上男生的數目是女生數目的三倍」。

(2) 舉例（Exemplifying）：學生對於一般性概念或是原則性知識，能給予一個特殊的示例，意指學生能找出一般概念或是原則性定義之特徵，使用這些特徵做選擇構成一個特殊的例子。

【示例】請畫出一個等腰三角形。

【示例】請舉例說明何謂「畢氏定理」?

(3) 分類（Classifying）：學生能確定或指認某物（一個特殊的例子）是屬於某一特定的類目（概念或是原則）。亦指找出相關的特徵，使其與概念或原則是相匹配的。

【示例】下列哪一個選項中的圖形都是平行四邊形?

(1)正方形、梯形、菱形　(2) 正方形、菱形、矩形

(3) 正方形、梯形、矩形　(4) 梯形、菱形、矩形

(4) 摘要（Summarizing）：學生對於呈現的資訊，提出陳述來表示或是提取出一般主題，也就是建構一個資訊表徵。

【示例】已知三角形的內角和是 180' ，那麼一個凸 n 邊形的內角和是多少度?

(5) 推論（Inferring）：學生能從目前資訊中獲得一個邏輯結論，也就是從一系列之示例中，發現相關的屬性與其之間的關係，進而取出一個程序或概念知識，其過程包含比較示例，指認出組型規則，使用此組型規則來產生符合此規則的新示例。

【示例】當 x = 1 時 y = 0；當 x = 2 日，y = l；當 x = 3 時，y = 2；請寫出一個方程式來表示 x 與 y 的關係。

(6) 比較（Comparing）：學生能覺察兩個以上的實體（例如：事件、物件、思想、問題或是情境）之間的相似與不同之處，也就是能於已知事物與新學事物之間找出異同關係。

【示例】下圖有 6 個三角形，請將彼此相似的三角形連起來，並寫出根據的性質。

(7) 解釋（Explaining）：學生能使用或是建構現象系統之連續因果模式，其包括建構因果模式、使用模式來了解系統因某部分的改變或是一連串事件中某個事件的改變是怎麼影響其他部分或事件之改變。

【示例】試解釋指數函數 y = f(x) = 2 為什麼是一個嚴格遞增函數。

3. 應用（Apply）

應用乃是使用程序（步驟）來完成練習或是解決問題。應用包含兩種能力，一種是例行性作業取向，也就是學生已經知道該使用哪個程序來執行任務；另一種是解決問題取向，也就是學生事先不知道該使用哪一種程序。應用又可細分為執行與實行。

(1) 執行（Executing）：當學生碰到的是熟悉的任務時，會例行地使用一組程序。

【示例】請以加減消去法解下列二元一次聯立方程式。

$$3x + 4y = 18$$

$$5x - 2y = 14$$

(2) 實行（Implementing）：當學生碰到的是不熟悉的任務時，必須先了解問

題，再從學過的程序中直接採用或是修改一組程序後採用。

【示例】已知一個等腰梯形的腰長 6 公分及一個底邊長是 4 公分，若還知道此腰與已知底邊的夾角是 60 度，求作此等腰梯形。

4. 分析（Analyze）

分析是將材料分解成它所組成之成分，指出成分之間與整體結構之關係，可分為辨別、組織以及歸因。

(1) 辨別（Differentiating）：學生能從所提供之材料中，根據材料各個部分之關聯性與重要性，區辨出相關或不相關、重要或不重要，也就是能寫出或指出相關或重要的資訊。

【示例】)已知 p = a^2- b^2，其中 p 為一質數，則 a 不可能是下列哪一個數?

(1) 2 (2) 4 (3) 6 (4) 8 (5) 10

(2) 組織（Organizing）：學生能辨認出結構中之各個元素，並且知道這些元素是如何統整在一起。

【示例】如下圖所示， ABCD 為一平行四邊形， E 為$\overline{\text{AD}}$上一點，F 為$\overline{\text{AC}}$與$\overline{\text{BE}}$的交點。若$\overline{\text{AE}}$：$\overline{\text{ED}}$ = 2：3 ，則$\overline{\text{AF}}$：$\overline{\text{FC}}$ = ?

(3) 歸因（Attributing）：學生能指出或決定目前資訊所呈現之有形觀點、偏見、價值以及意圖。然歸因超越基本之了解，重點在於推論事物背後所要表達之觀點與意圖。

【示例】(1) 利用圓規與直尺作一正方形，使它的面積等於一已知三角形 ABC 的面積。

(2) 設$\overline{AB}$=5，$\overline{BC}$=7，$\cos B=\frac{3}{5}$，求△ABC 的面積。

(3) 在(2)的條件下，求出所作正方形的邊長。(用去尾法算到小數點後第二位)。

5. 評估（Evaluate）

評估是根據規範與標準作判斷，可分為檢查與評論。

(1) 檢查（Checking）：在學習時，學生察覺過程與結果有矛盾或謬誤時，對於過程或結果進行內部是否具有一致性之確認動作，或是探查步驟是否是有效的被執行。

【示例】如右圖所示，O 為圓心，$\overline{AB}//\overline{CD}$，∠BAO=40 度，∠DCO=30 度，又知 CD 弧比 AB 弧大 16 度，則 AB 弧的度數為何?

(1) 120 (2) 102 (3) 100 (4) 62。

(2) 評論（Critiquing）：學生察覺操作、結果以及外在標準之間有矛盾時，判斷結果是否有外在一致性或問題的解決步驟是否適當。

【示例】有一位同學宣稱他發現一種判別 11 的倍數的方法，他的做法如下：

步驟一：將一個數分成兩部份:個位數與其他，例如將 132 分成 13 與 2。

步驟二：將其他部分的數減去個位數，例如前面的 13 - 2= 11

步驟三：如果步驟二所得減法的差是 11 的倍數，則原數就是 11 的倍數。如果數字太大則可以重複步驟一到步驟三。

請判斷這位同學用來檢驗 11 的倍數的作法是否正確?如果正確，請加以證明；如果錯誤，請舉一反例。

6.創造（Create）

創造是將各個元素組合在一起，以形成一個完整並具有功能性的整體；意指學生能透過重新組裝元素或重新組裝局部元素，使出現過去很少出現之結構或組型，可分為產生、計畫以及製造。

(1) 產生（Generating）：學生根據問題表徵，以形成滿足或符合規準之多種假設或可能性。

【示例】在△ABC 中，若已知$\overline{AC}^2+\overline{BC}^2 = \overline{BC}^2 > \overline{AB}^2$ 證明△ABC 是一個鈍角三角形。

(2) 計畫（Planning）：學生能設計滿足問題規準之解法，也就是能發展解決問題方法步驟之計畫。

【示例】將奇數按照規律，由上而下，由左而右排成下圖。請指出第九列的第 10 個數是____

1 第一列

3 5 7 第二列

9 11 13 15 17 第三列

19 21 23 25 27 29 31 第四列

33 35 37 39……………

(3) 製作（Producing）：學生能根據給予的目標，創造出滿足目標描述之產品，意指學生能執行明確之解決問題方案。

【示例】證明$\sqrt{2}+\sqrt{3}$為無理數。

除了六個教育目標之外，修訂版還將教育目標分分成兩部分：知識向度（knowledge dimension）和認知歷程向度（cognitive process dimension）（Anderson et al, 2001），前者為協助教師區分教什麼（what to teach），後者在促進學生保留（retention）和遷移（transfer）所習得的知識。

第五節　系統性文獻分析法

近年來，由於證據為本（Evidence-based Practice）的教育理念日益被國內外的學者重視與推廣，因此應用系統性文獻分析法（Systemic Review）為建立此理念最佳的方法之一。然而，面對各式各樣的個別研究證據，該如何有效地整合這些相關研究是相當重要的議題。系統性文獻分析法即能藉由收集、評估以及整合已存在之研究報告，進而提供實務者做決策之運用（謝進昌，2010）。

一、系統性文獻分析法之歷史演變

系統性文獻分析法之起源可以從 Feldman（1971）所提出的文獻系統性分析和整合（Systematic reviewing and integrating）之概念開始，其提出四個在分析中主要的步驟，包括搜尋高度相關文獻程序之策略、文獻整合的問題、整合之功能

以及整合之價值。在醫學領域中，當面對龐大的研究證據時，若使用傳統的敘事分析則無法將證據做有效的整合，且其傾向著重在研究範圍中的某一小部分而已，也無明確地說明如何選取相關的研究文獻，所以存在研究者自我偏誤、無法評估研究論文之品質以及相關研究論文無法做適當的整合等議題（Dixon-Woods et al, 2006；Tranfield, Denyer & Smart, 2003）。Cochrane 合作聯盟（The Cochrane Collaboration）為國際的非營利組織，成立於 1993 年，以建立證據為本的醫學與健康照顧（Evidence-based Medicine and Health Care）為目的，Cochrane 資料庫（Cochrane library）提供許多醫學領域相關的研究報告，並且針對各種的醫療介入之效果做系統性之分析。

然而，經過這幾年的演變，系統性文獻分析法被非醫學領域，例如心理、教育等社會科學領域的學者效仿，以從事類似的研究工作。在教育領域中系統性分析組織之發展歷史不長，但有基礎之架構（謝進昌，2010）。西元 1993 年英國倫敦大學成立 Evidence for Policy and Practice Information and Co-ordinating Centre（EPPI-Centre），針對一系列的主題進行系統性文獻分析，其領域包含：教育與社會政策（Education and social policy）、健康促進與公共健康（Health promotion and public health）、國際健康系統與發展（International health systems and development）以及參與研究與政策（Participative research and policy）等，而其相關資料皆可在 EPPI-Centre 網站證據資料庫（Evidence library）取得（EPPI-Centre Web Site, 2012）。此外，美國教育部亦於 2002 年成立 What Works Clearinghouse（WWC），目的為運用客觀的、透明化的標準和程序來系統性分析教育介入的相關研究之有效性，以及在科學證據上的價值（What Works Clearinghouse, 2011）。

不管是醫學還是社會科學領域，都企圖藉由系統性文獻分析法將累積的相關研究證據或知識，經由一個嚴謹的、系統性的文獻搜尋、選擇、評論等過程，來檢視能否有效幫助實務或政策之裁決。Evans 與 Benefield（2001）認為系統性文獻分析成功地運用在醫學領域上，若能將之適當地引導到教育的情境中運用，可

以將系統性文獻分析之研究視為一種呈現教育實務和政策累積效果的方法。

二、系統性文獻分析法之流程

系統性文獻分析法的過程和相關步驟已發展近十年了，目前在證據為本的實務中扮演相當重要的角色（Tranfield, Denyer & Smart, 2003）。系統性文獻分析法不同於傳統的敘事分析（narrative review），其為一個可複製的、科學的、以及明晰的過程，也就是透過一連串詳細的研究方法，將已出版或未出版的研究論文，藉由一連串詳盡的搜尋與審核進而做決定、實行程序步驟以及做結論（Tranfield et al, 2003）。不管使用系統性文獻分析法的目的為何，其有以下幾項特徵（Bronson & Davis, 2011）：

1. 企圖搜尋所有相關的研究文獻，包含已出版和未出版的文獻。
2. 從已存在的研究文獻中蒐集資料並將資料做有意義的整合。
3. 為了確定相關研究是否納入，必須清楚並詳細地說明包含和排除之準則。
4. 有明晰的搜尋文獻方法且此方法是可被複製的。

系統性文獻分析法整個流程包含確定研究主題與研究問題、搜尋相關研究論文、評估研究論文之品質、資料萃取、結果之綜合呈現與詮釋等步驟（Tranfield et al, 2003；Bronson & Davis, 2011），各個步驟之說明如下：

1. 定義研究問題與準備系統性分析計畫表

定義研究問題與發展系統性分析計畫表是相當重要的，因為此會影響到後續一連串的步驟，像是如何蒐集相關文獻與如何進行分析等等。

(1) 系統性分析之研究問題：

為驅動系統性分析和決定如何進行文獻搜尋，必須定義明確之研究問題。研究問題除了要符合系統性分析之研究目的，也要注意其範圍不宜太廣泛或太狹隘，因為太廣泛容易導致搜尋文獻出錯、不易制定文獻的包含或排除標準以及最後結論描述無法聚焦；太狹隘會導致符合標準的文獻太少，使得最後綜合的評論是有限的。所以訂定研究問題之前可以實施範圍的分析（Coping

Review）或是系統性之規劃（Systematic Mapping）。

(2) 準備系統性文獻分析之計畫表：

此計畫必須清楚地說明和解釋分析之方法，這份計劃表也表示此分析方法的可複製程度與最後結果的整體品質。而在進行相關文獻搜尋之前，分析者必須先清楚地敘述研究問題以說明搜尋文獻之重點，接著確定搜尋文獻的方法以辨識相關的資訊，並且訂定特定的包含和排除之標準以決定文獻是否該納入。一旦研究問題的範圍、文獻的搜尋方法、訂定文獻包含和排除之標準後就完成系統性文獻分析法之計畫。

2. 搜尋相關之研究文獻

在實施相關文獻的搜尋時，使用的搜尋策略應該廣泛，因為有些文獻雖不符合包含的標準，但卻具有參考的價值。而透過多種且廣泛的搜尋策略以取得相關文獻，可以降低文獻選擇偏誤（Selection Bias）之影響。此外，在進行文獻搜尋之前，應具體訂定文獻的包含和排除標準（Inclusion and Exclusion Criteria）以更能精確搜尋到欲搜尋的相關文獻。

(1) 文獻搜尋策略：

系統性文獻分析法強調使用徹底的搜尋策略（exhaustive search strategy），無論是已出版或未出版的文獻都是文獻搜尋的範圍。在操作上，先依據研究主題來列出相關且適當的搜尋字串，再選擇與主題相關的檢索系統或平台。文獻來源包含：電子資料庫、手動搜尋主要期刊、檢視先前系統性文獻分析中的參考文獻、訪談領域專家、搜尋灰色文獻（gray literature）。

(2) 文獻之包含和排除準則：

包含和排除準則主要是依據研究目的與研究問題來界定，它們有助於文獻搜尋，也決定了系統性文獻分析研究的外在效度、可推論性以及介入的策略等等。除此之外，納入研究分析的文獻之研究設計（準實驗或真實驗設計）、語言（英文或是其他語言）以及研究時間等也必須清楚界定。

3. 評鑑被包含文獻之品質

若將品質不佳的研究納入會對整合後結果產生不良的影響，而使得整合的結果呈現無意義或是完全錯誤，所以應該將搜尋到的文獻做品質的評估以避免發生上述情形。Higgins ＆ Greens（2006）認為沒有任何一項標準可以明確地評斷某個試驗的真實效度，因為其有限制性，但至少可以依循基本的原則來評估研究的品質。文獻品質的評估包含：研究方法之內在效度與外在效度以及研究者的可信度。

4. 資料萃取表

系統性文獻分析法如同將既存的研究資料做第二次分析，在進行分析之前，應該事先將資料萃取表格設計好（Bronson & Davis, 2011）。資料萃取表具有三個功能：

(1) 表格可以直接連結要分析的研究問題，計畫整合研究的評估。

(2) 在系統性分析過程中，表格扮演一個歷史紀錄的角色。

(3) 表格內容之資訊是從資料儲存庫（ data repository）中來分析。

資料萃取表依據研究的本質進行設計，是具有彈性的。分析者在設計資料萃取表時應考慮哪些資訊應被納入，而這些資訊將影響後續的資料整合與呈現。資料萃取表需詳細記錄蒐集到的文獻之各類資訊，包含一般的資訊（例如題目、作者、期刊以及出版物等等）、研究特徵以及特定的資訊，像是研究情境、研究細節以及研究法等（Tranfield, Denyer & Smart, 2003）。

5. 資料整合與結果呈現

將從大量且不同的文獻中發現的現象做適當的分類與整合。資料的整合與呈現方式有敘事分析、後設分析以及最真實的整合方法。分析者應該依據研究的目的與問題選取最適宜之方法。

三、系統性文獻分析法與後設分析流程圖

為了清楚說明系統性文獻分析法的文獻篩選流程，Moher et al（2009）提出系統性文獻分析法（Systemic Review）須以 PRISMA（Preferred Reporting Items for Systematic Reviews and Meta-Analyses）流程圖呈現分析過程之資訊，圖 2-2 即為

Moher et al（2009）所提出之文獻在各個階段搜尋流程資訊的示意圖，圖中最上方的兩個方塊記錄了從資料庫與其他來源共蒐集到的文獻篇數，中間各步驟包含將重複文獻刪除，接著訂定篩選文獻之準則，將不符合準則之文獻刪除並且清楚說明刪除之理由，以及評估保留文獻之品質，這些過程必須詳細記錄，最後則是將保留之文獻做綜合彙整。

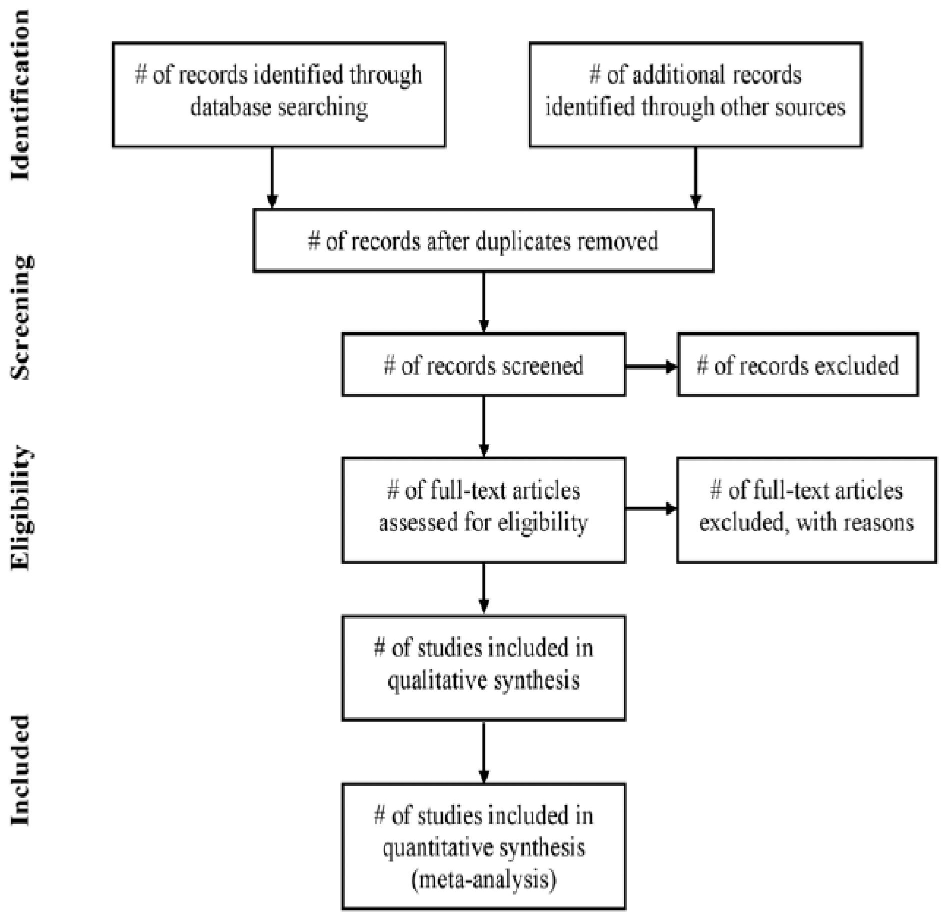


圖 2- 2 系統性文獻分析之不同階段資訊之流程（Flow of information through the different phases of a systematic review. (Moher et al)）

Gough, Oliver & Thomas（2012）將 Moher 等人所提出的 PRISMA diagram 用另一種方式呈現，如圖 2-3 所示，雖然呈現圖的方式不盡相同，但一樣可清楚知道整個文獻搜尋與篩選之過程，例如從流程圖中能得知經過瀏覽文獻標題與摘要後共刪除 13457 篇文獻，而這其中包含 1394 篇重複文獻，其餘的則是因不符合

文獻篩選準則，如主題、研究參與者年齡等，而被刪除。

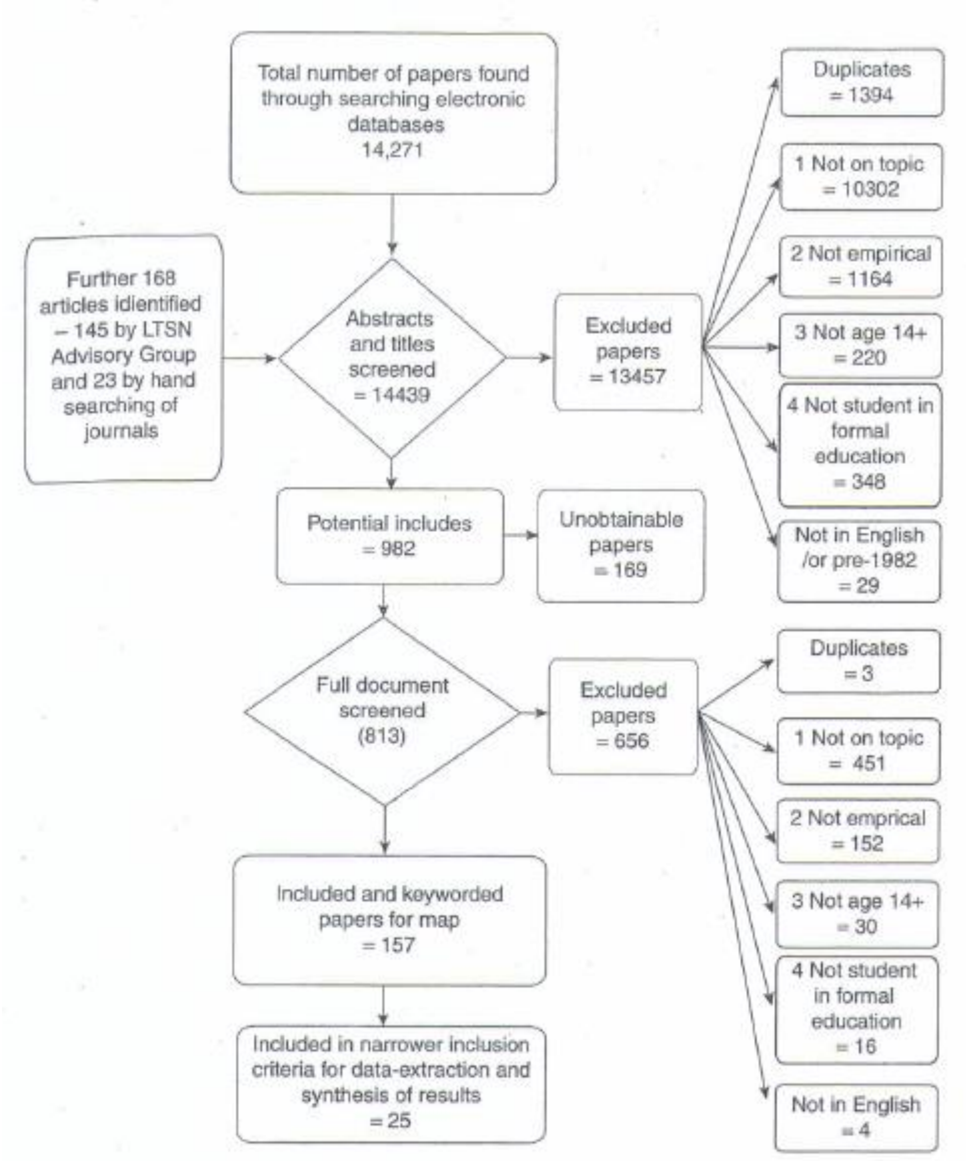


圖 2- 3 PRISMA diagram

本研究之系統性文獻分析法流程圖採用 Gough, Oliver & Thomas（2012）的方式，依據系統性文獻分析法之實施步驟繪製而成，如圖 2-4 所示，包含研究規劃、研究實施與研究分析階段，各實施細節將於第三章說明。

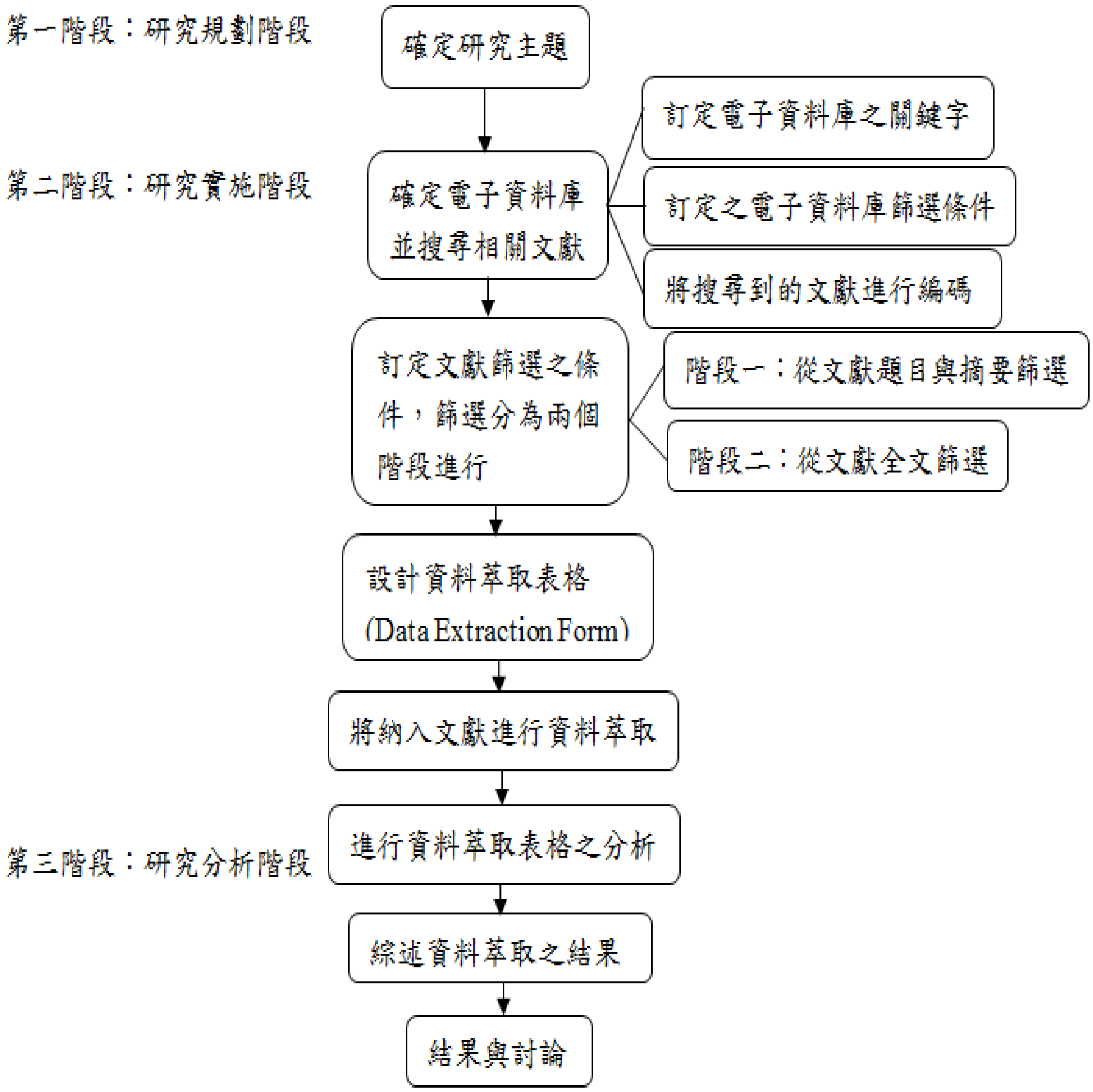

第一階段：研究規劃階段
確定研究主題
第二階段：研究實施階段
確定電子資料庫並搜尋相關文獻
訂定電子資料庫之關鍵字
訂定之電子資料庫篩選條件
將搜尋到的文獻進行編碼
訂定文獻篩選之條件，篩選分為兩個階段進行
階段一：從文獻題目與摘要篩選
階段二：從文獻全文篩選
設計資料萃取表格
(Data Extraction Form)
將納入文獻進行資料萃取
第三階段：研究分析階段
進行資料萃取表格之分析
綜述資料萃取之結果
結果與討論

圖 2- 4 研究流程圖

第三章　研究方法

本研究旨在探討資訊科技融入中小學數學科教學之情形，特別著重於研究有哪些資訊科技工具融入數學科教學、使用科技工具的方式、對教學的影響以及資訊科技有益於數學教學之特性。本研究採用之研究方法為系統性文獻分析法（Systematic Review），收集資訊科技融入中小學數學科教學之相關文獻並進行彙整分析。

本章共分為三節：第一節為研究設計與流程，說明研究架構、研究規劃、實施以及分析之流程；第二節為研究工具，說明本研究過程中所使用的研究工具之設計緣由；第三節是資料處理與分析，說明如何將萃取表所記錄的資料進行處理與分析。

第一節　研究設計與流程

本研究收集西元 2000 年 1 月至 2012 年 12 月期間以英文發表、且與資訊科技融入中小學數學科教學相關之期刊論文。研究流程分為三個階段，如上一章的圖 2-3 所示，分別為研究規劃、研究實施與研究分析階段，以下詳細說明各研究階段。

<u>第一階段：研究規劃階段</u>

研究實施前，先確定研究主題、動機與緣由。研究動機與緣由已於第一章中詳述，待主題確定後，周詳思考研究報告之來源，研究者就讀於國立臺灣師範大學，故可運用本校圖書館訂閱之相關期刊，此雖為研究限制之一，但本校是國內擁有最多教育相關資源的大專院校之一，故可較完整地搜尋到與研究主題相關之研究報告。

第二階段：研究實施階段

確定從國立臺灣師範大學的圖書館收集資料後，先決定搜尋研究報告所使用的搜尋字串，同時確定所欲搜尋的電子資料庫，運用訂定好的搜尋字串從電子資料庫取得文獻後，再依據文獻篩選條件進行兩階段之篩選，並且設計文獻資料萃取表，最後運用此表格進行文獻資料萃取。

一、訂定搜尋字串

本研究著重於探討資訊科技融入數學科之教學，將資訊科技視為教學工具以輔助教師之教學與學生之學習，且學科為數學，因此關鍵字是針對教學、科技以及學科這三個面向所訂定的，此外也將同義詞彙列出且使用萬用字元「*」，來擴大搜尋範圍。

1. 教學面

（teach* OR learn* OR educat* OR instruct* OR pedagogi*）：由於為資訊科技融入教學，故教學與學習之關鍵字是不可缺的。

2. 科技面

（ICT OR technology OR computer OR system）：由於將資訊科技視為教學工具，故科技面主要是針對融入教學之科技所訂定的。

3. 學科面

（math *）：由於本研究探討的學科為數學，故加入 math 一字。。

綜合以上三個面向，本研究之搜尋字串訂定為：（ICT OR technology OR computer OR system）AND（teach* OR learn* OR educat* OR instruct* OR pedagogi*）AND math*。

二、確定所欲搜尋之電子資料庫

電子資料庫之訂定分為兩個階段，一是根據國立臺灣師範大學圖書館對於各電子資料庫之介紹，以判別是否為與教育相關之電子資料庫；二是將訂定之搜尋

關鍵字輸入第一階段所篩選出來的電子資料庫，檢視每個電子資料庫所搜尋之文獻筆數，以決定是否要搜尋此電子資料庫。以下說明這兩個階段的過程：

1. 根據資料庫簡介進行篩選

從國立臺灣師範大學圖書館網站進入電子資料庫總覽後，點選「英文檢索」，總共有 168 個電子資料庫，接著，根據電子資料庫之內容介紹以進行篩選。本研究採用之電子資料庫必須與社會科學之教育相關，在此階段保留 ISI Web of knowledge 等十個電子資料庫，如表 3-1 所列。

2. 確定搜尋文獻之資料庫

將訂定好的關鍵字輸入至第一階段所得之 10 個電子資料庫，並瀏覽搜尋結果，以確定是否使用此資料庫，表 3-1 列出各電子資料庫被刪除或保留的原因，例如 JSTOR Arts & Sciences I Collection 的簡介中提及有收錄教育學方面期刊，但使用本研究訂定之關鍵字沒有搜尋到相關文獻，故將此電子資料庫刪除。

表 3-1 電子資料庫篩選過程

編號	電子資料庫名稱	電子資料庫內容簡介	選擇或刪除之原因
1	ISI Web of knowledge	提供研究人員、決策者、教職員與學生最迅速、強大的引文索引資料庫。收錄全球最權威、橫跨各學科領域多達 10,000 種期刊資源，其中包括多種公開取用（Open Acess）期刊以及超過 110,000 種會議紀錄。透過 Web of Science®可以找到最新以及回溯的科學、社會科學、人文與藝術等 256 個學科領域的豐富資訊，資料最早可回溯至 1900 年。	此資料庫有涵蓋教育方面的資料，關鍵字搜尋後，得到 5120 篇文獻，其中有相關文獻，故選之。
2	Education Journals（ProQuest 系統）	收錄 740 餘種期刊索摘（1994-），及其中 580 餘種期刊之全文（1996-）。	關鍵字搜尋後，得到 96668 篇文獻，其中有相關文獻，故選之。
3	ERIC（EBSCO）	全球最大之教育資源網站，查詢年代溯於 1966 年超過 1,100,000 筆之書目資料，亦收錄逾 107,000 筆非期刊全文文獻。	此資料庫有涵蓋教育方面的資料，關鍵字搜尋後，得到 31562 篇文獻，其中有相關文獻，故選之。
4	Ed/ITLib（Education & Information Technology Library）	該資料庫原名 AACE Digital Library，是由美國 Association for the Advancement of Computing in Education（簡稱 AACE）所建置。收錄內容為教育科技及 E-learning 相關領域，經同儕評鑑並已出版之期刊文章與會議論文集之電子全文。	此資料庫有涵蓋教育方面的資料，關鍵字搜尋後，得到 966 篇文獻，其中有相關文獻，故選之。

表 3-1 電子資料庫篩選過程（續）

編號	電子資料庫名稱	電子資料庫內容簡介	選擇或刪除之原因
5	ACM Digital Library	ACM 是全球第一個電腦教育及科學機構，為最具權威及前瞻之領導者。ACM Digital Library 是由 ACM 所出版的電腦資訊科技相關全文電子資料庫，可查找重要電腦領域文獻之書目資訊及摘要，收錄豐富且詳盡的書目資訊、雜誌與期刊、會議文獻紀錄，內容總計超過 1,200,000 頁的資料，與 CrossRef 協助合作，提供 DOI 及 Reference 和 Citings 相關連結。	以年份及關鍵字搜尋完，共 3 筆，其中無相關文獻，故不選之。
6	EBSCOhost 系統	主要提供 EBSCO 綜合學科、商管財經、生物醫護、人文歷史、法律等期刊之電子全文資料庫，以及部分當今全球知名之索引摘要資料庫，使用時可參考相關資源。	此資料庫有涵蓋教育方面的資料，關鍵字搜尋後，得到 5759 篇文獻，其中有相關文獻，故選之。
7	JSTOR Arts & Sciences I Collection	收錄以人文社會領域為主之非裔美人研究、人類學、亞洲學、經濟學、生態學、數學、哲學、政治學、教育學、財政、歷史、文學、人口統計學、社會學、統計學等 15 種學科之 119 種學術性過期期刊全文資料。	關鍵字搜尋後，得到 0 篇文獻，故不選之。
8	OmniFile Full Text Select（H.W. Wilson）	收錄 Applied Science & Technology Full Text 、Art Full Text 、Biological &	進入畫面與 EBSCOhost 系統同一個系統畫面，故不選之。

表 3-1 電子資料庫篩選過程（續）

編號	電子資料庫名稱	電子資料庫內容簡介	選擇或刪除之原因
8	OmniFile Full Text Select（H.W. Wilson）	Agricultural Index Plus、Education Full Text、General Science Full Text、Humanities Full Text、Index to Legal Periodicals Full Text、Library Literature & Information Science Full Text、Readers' Guide Full Text、Social Sciences Full Text、Wilson Business Full Text 等 11 個資料庫之期刊索摘及全文。	
9	Oxford Journals Online	收錄 Oxford University Press 所出版之 187 種電子期刊。	此資料庫並無教育相關的電子期刊，其內容多為各領域知識的探討，故刪除之。
10	University of California eScholarship Repository	加州大學學術期刊論文，收錄 142 種以上的 journals。	關鍵字搜尋後，得到 0 篇文獻，故不選之。

經過電子資料庫之兩階段篩選，最後確定使用五個電子資料庫，包含 ISI Web of knowledge、Education Journals（ProQuest 系統）、ERIC（Proquest）、Ed/ITLib（Education & Information Technology Library）以及 EBSCOhost 系統進行文獻搜尋。正式使用電子資料庫搜尋文獻時，除了前述之搜尋字串，還有幾項搜尋條件如下，每個電子資料庫的搜尋介面有所差異，將視其實際情形進行調整：

(1) 年份：西元 2000 年至 2012 年

(2) 文章類型：期刊文章

(3) 語言：英文

(4) 文章主題：與資訊科技融入教學相關

(5) 關鍵字：（ICT OR technology OR computer OR system）AND（teach* OR learn* OR educat* OR instruct* OR pedagogi*）AND math*

本研究使用電子資料庫搜尋文獻的時間為西元 2013 年 3 月中旬，各電子資料庫搜尋過程之電腦螢幕截圖如附錄一。每個電子資料庫依據搜尋條件所得到的文獻筆數說明如下：

1. ISI Web of knowledge：當輸入關鍵字後，搜尋所得筆數為 5,120，再加入搜尋條件 Publication years（2000-2012）與 Subject area（Educational Research）後，搜尋所得文獻筆數變為 1,130。
2. Education Journals（ProQuest 系統）：當輸入關鍵字後，搜尋所得筆數為 96,668，再加入搜尋條件 Peer reviewed & Source type、Language & Publication data（2000-2012）、Publication title 以及 Document type 後，搜尋所得文獻筆數變為 6006。
3. ERIC（Proquest）：當輸入關鍵字後，搜尋所得筆數為 31,526，再加入搜尋條件 Peer reviewed & Source type、Language & Publication data（2000-2012）、Subject 後，搜尋所得文獻筆數變為 2,059。
4. Ed/ITLib（Education & Information Technology Library）：當輸入關鍵字後，搜尋所得筆數為 966，再加入搜尋條件 Publication years（2000-2012）後，搜尋所得文獻筆數變為 925。
5. EBSCOhost 系統：當輸入關鍵字後，搜尋所得筆數為 5,759，再加入搜尋條件 Scholarly Journal（Peer Reviewed）、Published Data from 2000-2012、Subject Type 以及 Subject 後，搜尋所得文獻筆數變為 1,502。

由此階段開始，本研究繪製「文獻搜尋與篩選流程圖」（圖 3-1），以呈現各搜尋與篩選階段之文獻數量。從五個電子資料庫搜尋的結果，文獻筆數有 11,622 篇，為了能有效管理大量的文獻，本研究使用文獻管理軟體 Endnote 將電子資料庫搜尋所得之文獻匯出至 Endnote 軟體中，以利後續的文獻編碼與篩選。

將文獻從電子資料庫匯入 Endnote 軟體後，運用 Endnote 軟體功能刪除重複的 1,313 篇文獻，數量降至 10,309 篇。接著將此 10,309 篇文獻列表匯入至 Microsoft Excel 軟體，最後給予每篇文獻專屬的流水號，此流水號目的是便於記錄後續的文獻篩選過程。

三、篩選文獻

文獻篩選分為兩個階段，階段一從文獻之題目與摘要進行篩選，其必須與資訊科技融入教學相關；階段二進行全文篩選，文獻內容必須包含能分類填入資料萃取表格之有用的訊息以進入資料萃取與分析。篩選文獻時是依據文獻篩選條件來決定的，兩階段之篩選條件說明如下：

1. 針對文獻的題目與摘要進行篩選，此階段篩選條件如下：
   (1) 必須是資訊科技（ICT）融入教學
   (2) 資訊科技融入之科目：數學科
   (3) 實驗對象：中小學（K-12）
   (4) 實驗場域：教室（Class-based）
2. 針對文獻全文內容進行篩選，文獻內容必須具有教師、學生與科技三方面的資訊，說明如下：
   (1) 教師面：教師如何使用科技進行教學
   (2) 學生面：學生如何使用科技進行學習
   (3) 科技面：科技融入教學對教師/學生之教學與學習成效之影響

依據上述三個面向，訂定出以下四個篩選條件，此階段篩選條件具有循序漸進的作用，當文獻不符合篩選條件 1 時，就不必考慮篩選條件 2，以此類推，此階段篩選條件如下：

(1) 有清楚說明融入教學之科技工具

(2) 有清楚敘述整個學習活動

(3) 有清楚說明科技融入對教學之影響

(4)　有清楚說明研究方法

進行兩個階段的文獻篩選時，本研究使用「文獻篩選表格」進行記錄，以便後續資料萃取，文獻篩選表格之設計將於本章第三節研究工具中詳述。

四、文獻篩選結果

本研究經過一連串的篩選步驟，圖 3-1 將各篩選步驟刪除與保留之文獻數量列出。如前所述，從五個電子資料庫中共取得 11,622 篇文獻，刪除重複文獻後剩下 10,309 篇。研究者將這些文獻編號後，首先依據期刊簡介與發行宗旨篩選文獻，結果得知非學術性質期刊收錄之文獻有 24 篇，而非相關主題（not on topic）期刊收錄之文獻有 2,510 篇，故此步驟後，文獻數量降至 7,775 篇。研究者接著依據文獻之標題與摘要內容篩選文獻，其中高等教育有 462 篇，而與研究主題無關有 7,082 篇。經此步驟後，文獻量降至 231 篇。在閱讀全文之後，發現其中無清楚描述學習活動者有 63 篇，無描述科技工具特性有 28 篇，無嚴謹研究方法有 4 篇，與 ICT 無關有 20 篇，其他（包含非 K-12、介紹科技工具、問卷調查、無全文）有 45 篇。最後確定進入資料萃取與分析階段的文獻有 71 篇。

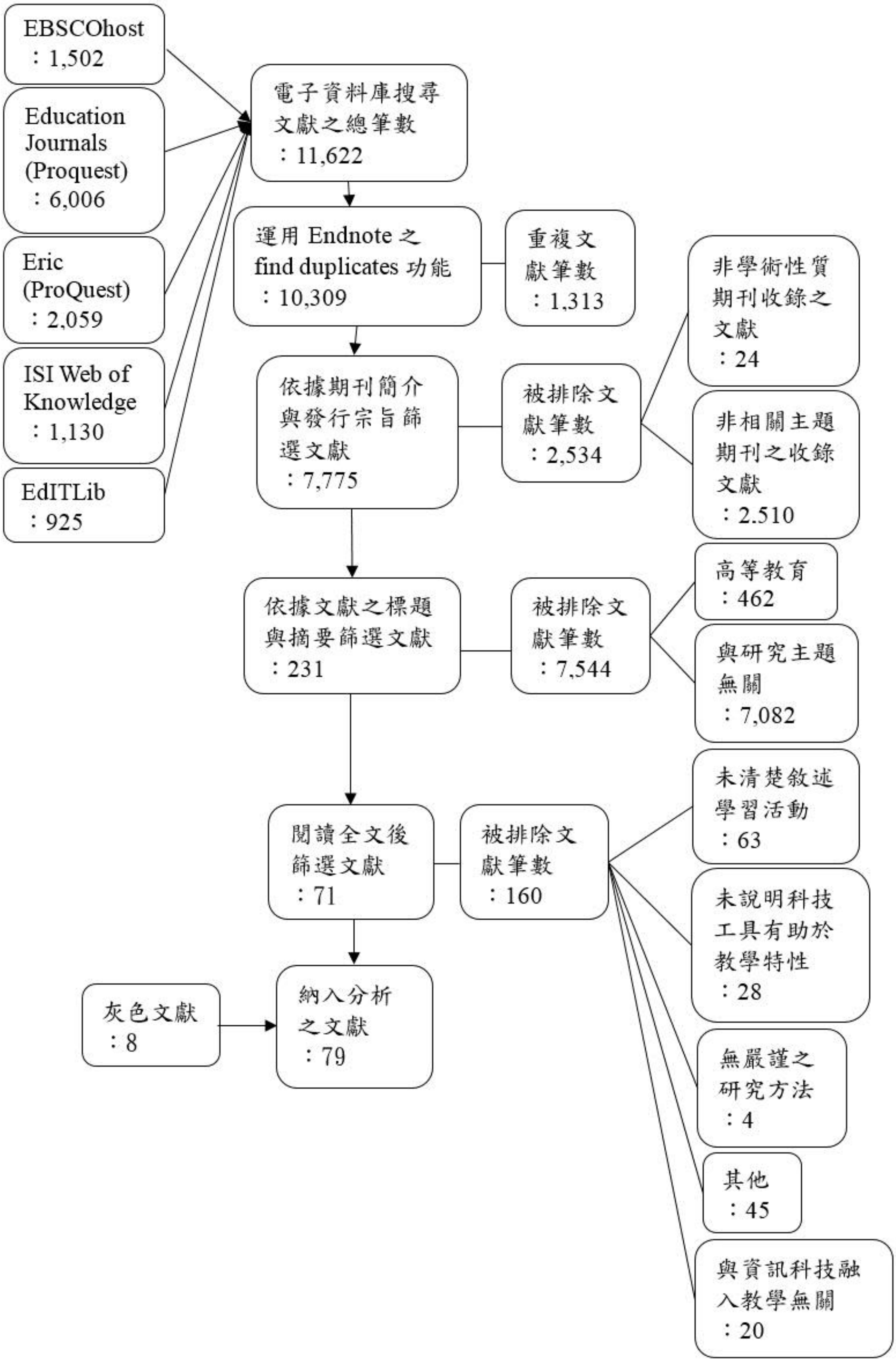


圖 3- 1 文獻搜尋與篩選之流程圖

五、灰色文獻（Gray Literature）之搜尋

灰色文獻是指「應被搜尋到，卻因文獻尚未出版或沒有收錄於搜尋之電子資料庫中，而未被找到之文獻」(Denise et al, 2012)。由於研究者無法預先得知整個資訊科技融入中小學數學科之教學相關文獻的母體數，再加上文獻資源之取得來源為國立臺灣師範大學所訂閱之社會科學相關期刊，因此推測有該納入分析而未被找到的文獻存在於此些期刊之外。為了達到文獻搜尋之完整性並將研究限制降至最小，本研究檢視被納入分析之文獻中的「參考文獻列表」，確認是否有本研究未搜尋到，但與本研究主題高度相關之文獻，若有，則視為本研究之灰色文獻，並將之納為分析文獻。

本研究之灰色文獻為確定納入分析之文獻的參考文獻中與本研究主題高度相關卻無被搜尋之相關文獻，最後灰色文獻一共為 28 篇。這些灰色文獻經過前述文獻篩選條件進行篩選後，確定納入分析的有 8 篇，如圖 3-1 所示。

第三階段：研究分析階段

將資料萃取表格之各個欄位所萃取到的資料進行分析並綜述資料萃取之結果。資料分析結果將於第四章中詳細敘述。

第二節　研究工具

以下說明本研究所使用之資料萃取表。

資料萃取表（表 3-2）是依據本研究之目的所設計的，其目的為將文獻中有用之資訊萃取出來，以達到本研究之目的與回答本研究之議題，請見表 3-2。資料萃取表格之欄位可分為兩種，一為文獻基本資訊欄位，另一為萃取資料欄位。文獻基本欄位包含文獻來源、研究目的、研究問題、研究方法、所收集之研究資料、教學單元、教學主題、教育階段等八個欄位；萃取資料欄位則包含融入教學之工具、學習活動(Learning activity)、研究結果、科技工具之特點等四個，各個欄位之說明如下：

1. 文獻來源、教學單元、教學主題、教育階段等文獻之基本資料。
2. 研究目的與研究問題：為被分析文獻之基本資料，可以判斷此篇文獻是否為關注於資訊科技融入對教學的影響。
3. 研究方法與所收集之研究資料：為被分析文獻之基本資料，可檢視此篇文獻研究之嚴謹度與品質，以確保其研究結果之可信度。
4. 融入教學之工具：為了綜合整理融入數學科教學之資訊科技工具種類，並且深入分析其融入之情形與對教學之影響，故此欄位是必要的。此欄位之內容將可回答研究議題 1。
5. 學習活動：包括教學策略與整個學習活動，此為最重要的萃取資訊。藉由檢視學習活動，可得知資訊科技工具是如何融入教學中，以及學生如何使用科技以達到並提升認知層次。此欄位之內容將可回答研究研究議題 3。
6. 研究結果：為萃取資料欄位，可知資訊科技的融入是否真的有助於提升教學成效。
7. 科技有助於學生學習之特性：探討每一種資訊科技工具之特性，並將同一種類資訊科技工具有助於教學的理由做綜合整理，以分析教師/學生是如何使用科技所具備的特性，以提升教學之效益。此欄位之內容將可回答研究議題 2。

根據以上說明後，資料萃取表格（Data Extraction Form）如表 3-2 所示。

表 3-2 文獻篩選表格

文獻編號：	
Data Extraction Form	
文獻來源	
研究目的	
研究問題	
研究方法	
教學單元	□數與運算(Number & Operations) □代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	
教育階段	□國小 □國中 □高中
融入教學之工具	
學習活動 (Learning activity)	教學策略：
所收集之 研究資料	
研究結果	
科技工具之特點	

第三節　資料處理與分析

本研究的分析資料為資料萃取表格之欄位內容，針對教育階段、教學單元、融入教學工具、學習活動、研究結果以及科技工具特點，從這些欄位所萃取的資料做進一步分析，企圖發現目前資訊科技融入中小學數學科教學之概況。首先，針對教育階段與教學單元進行彙整，了解科技工具融入數學科教學於哪一個教育階段與哪一個教學單元是最普遍的。接著，從融入教學工具面向切入，將科技工具進行分類，以了解目前融入數學科教學之科技工具有哪幾種並且以哪一種為最主要的。然後，從學習活動與教學之方式面向切入分析，歸納學生在學習活動中是如何使用這些科技工具，以了解學生因有了科技工具輔助其學習之後，而使得

其認知層次可達到哪一階層。最後，分析與彙整科技工具之特點，了解科技工具具備哪些特性或功能是有助於提升學生之學習成效。

本研究資料彙整與分析方法分為兩種，一種是類別之統計資料彙整，包含「教育階段」、「教學單元」、「融入教學工具」；另一種則是運用質性方式彙整、編碼及分析「融入教學之工具」、「學習活動」、「研究結果」以及「科技工具之特點」。以下詳述這兩種分析資料彙整與方法。

一、類別之統計資料彙整

萃取資料表之「教育階段」、「教學單元」、「融入教學工具」欄位，以統計方式進行匯整：

1. 從國小、國中及高中各佔文獻篇數比例以得知資訊科技融入數學科教學之教育階段情況。
2. 從數學科之五大教學單元所佔比例以得知資訊科技工具在各個教學單元融入之情況，並說明各個教學單元包含哪些教學主題。
3. 從融入教學之科技工具分類以得知數學科有哪些工具種類融入教學，且最常使用與主要有哪些種類。

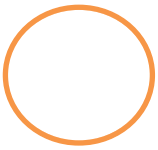
二、學習活動之質性資料彙整、編碼及分析

將萃取資料表格之「融入教學之工具」、「學習活動」、「研究結果」以及「科技工具之特點」欄位內容以「分析圖」方式呈現，接著，針對學習活動部分進行資料編碼，最後彙整與分析。本研究「分析圖」是指依據上述四個欄位之萃取內容進行圖示分析。從每一篇文獻之分析圖可以清楚得知科技工具是如何融入整個學習活動以及影響與成效。

（一）分析圖之繪製

分析圖以外框形狀代表不同的意義，一共有五種顏色與六種形狀，說明如下：

1. 硬體：

2. 軟體：

3. 教師使用科技工具之描述：

4. 學生使用科技工具之描述：

5. 研究結果：

6. 科技特性：

分析圖之箭頭表示教學過程方向，其為由左至右。最左邊為融入科技工具，分為軟體與硬體兩種，軟體以圓形表示，而硬體則以圓角的長方形表示。接著為學習活動，學習活動包含學生、教師操作科技工具以及實施教學策略。教師操作是以上方左右兩個凹角的長方形表示，學生則是以左下與右上兩個凹角的長方形表示。研究結果呈現在分析圖的最右邊，研究結果是說明科技工具融入後對教學產生之影響，以長方形外框表示之。軟、硬體下方為科技工具特性，其說明該工具具備那些特性益於教學，以左上凹角的長方形表示。軟體與硬體之間以無箭頭的線段進行連結，表示兩者為搭配使用。

以虛擬教具、圖形計算機以及動態幾何軟體這三個不同科技工具融入數學科教學為例，說明本研究分析圖之繪製與呈現方式。

1. 虛擬教具，以文獻編號 6211 為例，該文獻的分析圖如圖 3-2，說明如下：

   此篇為使用虛擬教具融入加法與減法學習。虛擬教具為軟體，故融入科技工具以圓圈表示。學習活動包含教師與學生使用，教師部分以「上方左右兩個凹角的長方形」表示，教師操作虛擬教具以範例說明虛擬教具操作方式；學生部分以左下與右上兩個凹角的長方形表示，學生使用虛擬教具練習加法與減法，待學生熟悉虛擬教具之操作後，進行分數學習。教學策略為學生獨自

操弄虛擬教具進行分數學習、學習過程中教師給予學生講義輔助學生獨自學習以完成學習活動。研究結果以長方形外框表示，結果為有顯著改善學生分數概念性與程序性知識、學生對使用虛擬教具抱持正向態度、學生喜歡虛擬教具的立即回饋、學生認為虛擬教具相較於使用紙筆學習是比較容易且快速使用、使學生有正向的學習經驗。科技工具以左上凹角的長方形表示，造成這些研究結果是因為科技工具具有動態影像、立即回饋與特定回饋、可提供個別化的學習以及多重表徵（文字、圖像以及數字）等特性，此些特性有助於學生學習分數。

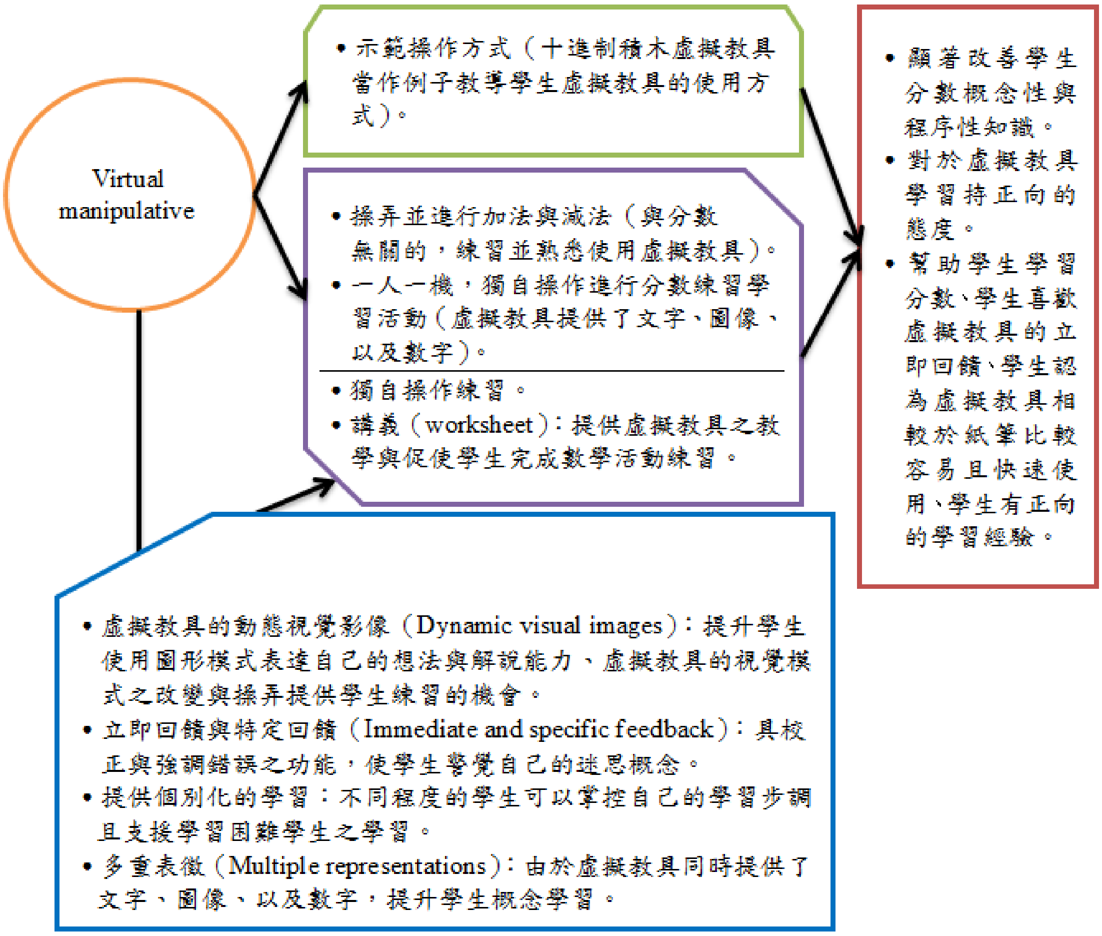


圖 3- 2 文獻編號 6211 之分析圖

2. 圖形計算機，以文獻編號 769 的分析圖為例（圖 3-3）說明如下：

此篇為使用圖形計算機搭配遊戲軟體學習統計概念。圖形計算機、投影機為硬體，則以圓角的長方形表示之，遊戲為軟體，則以圓形表示之。由於圖形計算機與遊戲兩者之間是以無箭頭的線連接，可知圖形計算機搭配遊戲軟體，且遊戲軟體是在圖形計算機上被操作。而同是硬體之投影機其箭頭與圖形計算機箭頭指向同一個教師使用科技工具框，表示教師使用此兩個硬體設備進行投影功能。學習活動為學生操作圖形計算機上的遊戲軟體產生統計資料與問題表格、做運算、創造表格以探索數學概念，教學策略為學生單人或兩人一組的方式進行統計概念學習活動，而教師將學生的圖形計算機畫面透過投影機投射出來。研究結果為學生對圖形計算機融入統計概念學習抱持正向態度並且給予正面評價。由於科技工具具有立即回饋特性，此對於學生之學習有正向影響。

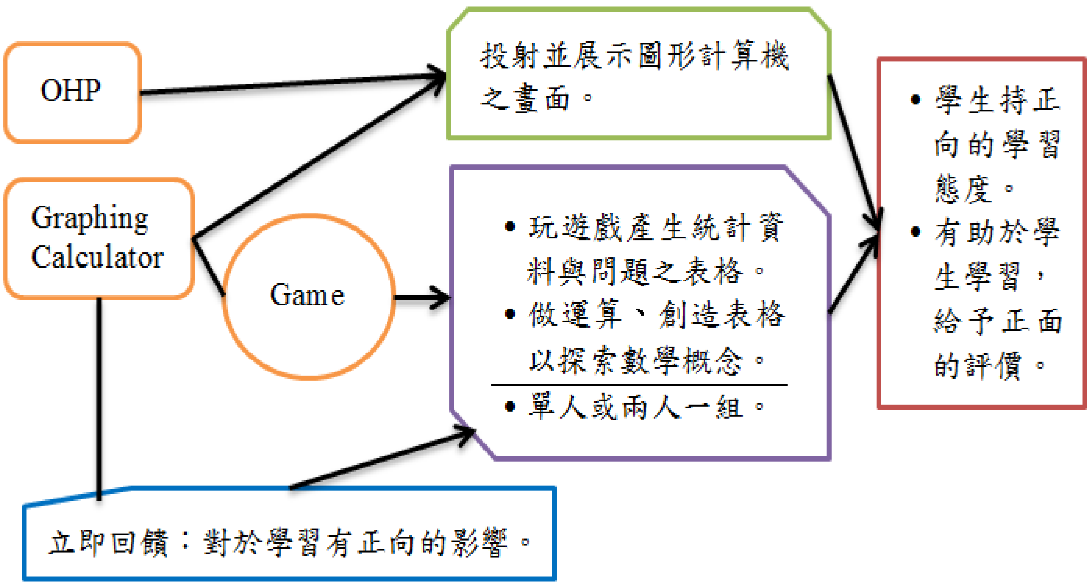


圖 3- 3 文獻編號 769 文獻之分析圖

3. 動態幾何軟體，以文獻編號為 1358 的分析圖為例（圖 3-4）說明如下：

此篇為使用動態幾何軟體學習幾何圖形。Cabri 為動態幾何軟體，故融入科

技工具以圓圈表示。學習活動則包含教師操作動態幾何軟體 Cabri 教導學生軟體操作與功能，待學生熟悉軟體功能後，進行學習活動。學生根據學習單上的教學，一步一步建構幾何圖形轉換、藉由拖拉幾何物件觀察幾何圖形動態轉換、探索幾何圖形轉換特性、驗證以及學習單紀錄解說。教學策略為學習單（教導如何建構幾何圖形之轉換、記錄操弄幾何轉換與解說）、學生獨自探索幾何、課堂討論（針對獲得結果做討論）。研究結果為提升學生幾何轉換學習成就。而科技工具具有動態性、學生可自我控制學習步調、給予學生回饋、實際操弄特性，此些特性有助於學生學習幾何、提升理解以及有正向的影響。

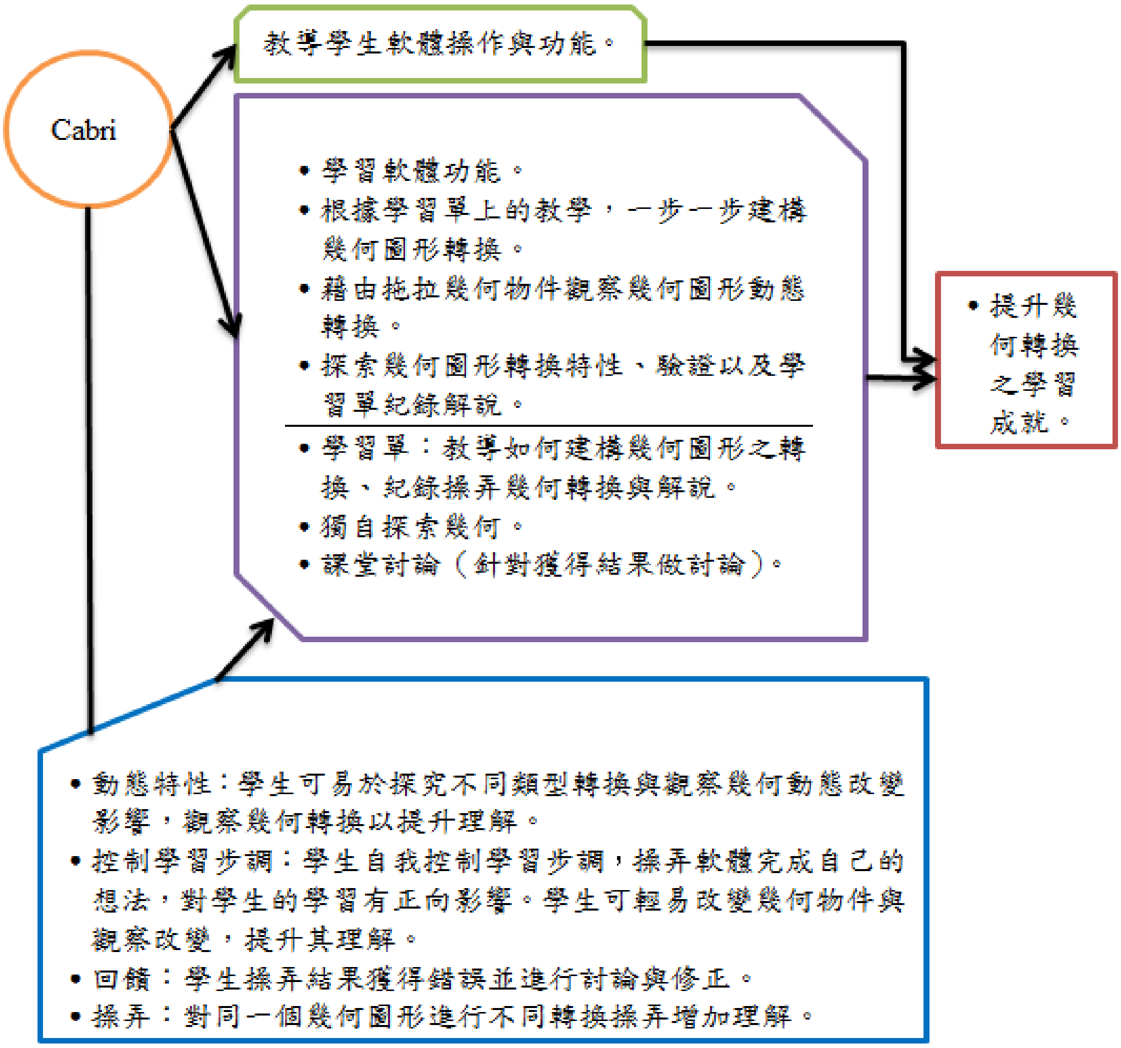


圖 3- 4 文獻編號 1358 之分析圖

每一篇納入分析文獻皆依照此方式畫出分析圖後，若以同一類科技工具進行彙整，將可得知各類科技工具是如何被教師或學生使用、具有哪些有助於學習之特性及為教學所帶來的成效如何。

（二）學習活動之編碼

分析圖之學習活動編碼是根據 D. R. Krathwohl（2002）修訂布魯姆（Benjamin S. Bloom）認知領域（Cognitive Domain）教育目標分類表之版本，最後進行彙整與分析。修訂版之六個認知過程層次及其十九個次類項之定義與相關示例已於第二章第三節中以示例說明，完整之資料彙整與分析結果，將於第四章闡釋。

第四章　結果與討論

本章呈現資料萃取表彙整與分析結果，並且根據這些結果進行更深入的說明與討論。第一節說明資訊科技工具融入中小學數學科之教學現況，針對教育階段、教學單元以及科技工具種類等三個面向討論；第二節說明各種科技工具具備哪些有助於教學之功能或是特性；第三節運用 D. R. Krathwohl（2002）之布魯姆（Benjamin S. Bloom）認知過程修訂版，檢視科技工具融入數學科教學後，學生進行了哪些學習活動，並且了解這些學習活動是如何提升學生之認知層次。

第一節　資訊科技融入中小學數學科教學之現況

本節為彙整資料萃取表格中「教育階段」、「教學單元」、「融入教學之工具」三個欄位之結論。依序彙整科技工具融入數學科教學的情況與科技工具類型有哪些，以了解目前資訊科技融入中小學數學科之現況。

一、科技工具融入數學科教學之教育階段

為了解資訊科技融入中小學數學科教學情況，將納入全文分析之文獻作為總數，一共 79 篇文獻，分別統計國小與中學所佔篇數，結果如表 4-1 所示：

表 4- 1 資訊科技融入數學科教學之「教育階段」次數分配表

教育階段	篇數	百分比
國小	35	44.3 %
國中	28	35.4 %
高中	16	20.3 %

由此結果可得知，目前資訊科技融入數學科教學於國小階段最為普遍，其次是國中階段，而高中階段是最少的。

二、科技工具融入數學科教學之教學單元

為了解資訊科技融入數學科教學於數學五大單元之情況，本研究統計資料萃取表格中「教學單元」欄位，以計算資訊科技工具融入各個單元之次數，結果如表 4-2 所示：

表 4- 2 資訊科技融入數學科教學之「教學單元」次數分配表

教學單元	個數	百分比
數與運算	28	28.6%
幾何	27	27.6%
代數	24	24.4%
資料分析與機率	10	10.2%
測量	9	9.2%

從表 4-2 可得知數與運算、幾何以及代數三大單元較常使用科技工具進行教學，尤其數與運算單元占所有文獻的 28.6%最多，其次是幾何單元，其占 27.6%。數與運算及幾何單元兩者只差 1%，所以在文獻的比例上是差不多的。而測量單元最少，僅不到一成的比例。此結果與 Moyer 等人（2008）針對教師於數學科教學過程中融入科技工具的結果相符。其研究結果顯示，由於學生學習數學表徵符號之轉換與關係常常出現學習困難，所以大多數的教師常將科技工具融於數與運算和幾何此兩大主題以輔助教學與學生學習。

然而，在數與運算單元中，其教學主題有分數同分母加法與減法、異分母加法與減法、分數乘法與除法、等值分數概念、分數比大小、分數與小數之轉換、整數加減乘除法、等差數列、估算策略以及比率之計算等。其中，以分數為教學主題為最多，其次是整數加減乘除之運算；在幾何單元中，其教學主題有幾何圖形結構與其特性、幾何圖形轉換、幾何圖形之對稱、球體，圓柱體，長方體，圓錐體等。其中，以幾何圖形之結構與特性為最多，其次是幾何圖形之轉換；在代數教學單元中，其教學主題有多項式方程式特性與圖形、函數圖形與推論、空間向量概念、初等微積分概念及方程式解題等。其中，以為多項式方程式特性最多，

其次是函數相關概念；在資料分析與機率教學單元中，其教學主題有機率概念、統計相關圖形及統計理論與推論等。其中以統計相關圖形為最多，其次是機率概念；在測量教學單元中，其教學主題有長度、面積及體積之測量。其中，以面積測量為最多，其次是體積測量。

三、科技工具融入數學科教學之工具種類

為了解至今有哪些科技工具融入數學科教學，彙整資料萃取表格中「融入教學之工具」欄位，進行分類並且統計各類科技工具於這些文獻中被使用的情形。科技工具分為硬體與軟體兩大類，以下依此兩類個別說明，硬體部分如表 4-3 所示：

表 4- 3 資訊科技融入數學科教學之「硬體科技工具」次數分配表

硬體名稱	個數	百分比
桌上型電腦	61	68.5 %
圖形計算機	10	11.2 %
電子白板	9	10.1 %
筆記型電腦	4	4.5 %
平板電腦	3	3.4 %
掌上型電腦	2	2.3 %

由表 4-3 可知，硬體部分包含桌上型電腦、圖形計算機、電子白板、筆記型電腦、平板電腦、投影機、以及掌上型電腦。從硬體科技工具各佔的百分比得知，目前資訊科技工具融入國中小數學科教學以桌上型電腦為主（68.5 %），其次為圖形計算機（11.2 %）與電子白板（10.1 %）。而軟體部分則如表 4-4 所示：

表 4- 4 資訊科技融入數學科教學之「軟體科技工具」次數分配表

軟體名稱	個數	百分比
虛擬教具	16	19.2 %
動態幾何軟體	13	15.6 %
指導式軟體	13	15.6 %
遊戲式軟體	7	8.4 %
辦公用套裝軟體	7	8.4 %
電子白板之內建軟體	5	6 %
圖形計算機之內建軟體	9	10.9 %
問題解決軟體	4	4.8 %
反覆練習軟體	3	3.6 %
掌上型電腦之內建軟體	2	2.4 %
討論平台之軟體	2	2.4 %
模擬軟體	1	1.2 %
程式設計軟體	1	1.2 %

由表 4-4 可知，軟體部分包含虛擬教具、動態幾何軟體、指導式軟體、遊戲式軟體、辦公用套裝軟體、電子白板之內建軟體、圖形計算機之內建軟體、問題解決軟體、反覆練習軟體、掌上型電腦之內建軟體、討論平台之軟體、模擬軟體及程式設計軟體。從軟體科技工具各佔的百分比得知，融入數學科教學的軟體以虛擬教具為主（19.2%），其次為動態幾何軟體（15.6%）與指導式軟體（15.6%）；而模擬軟體（1.2%）與程式設計軟體（1.2%）為最少。

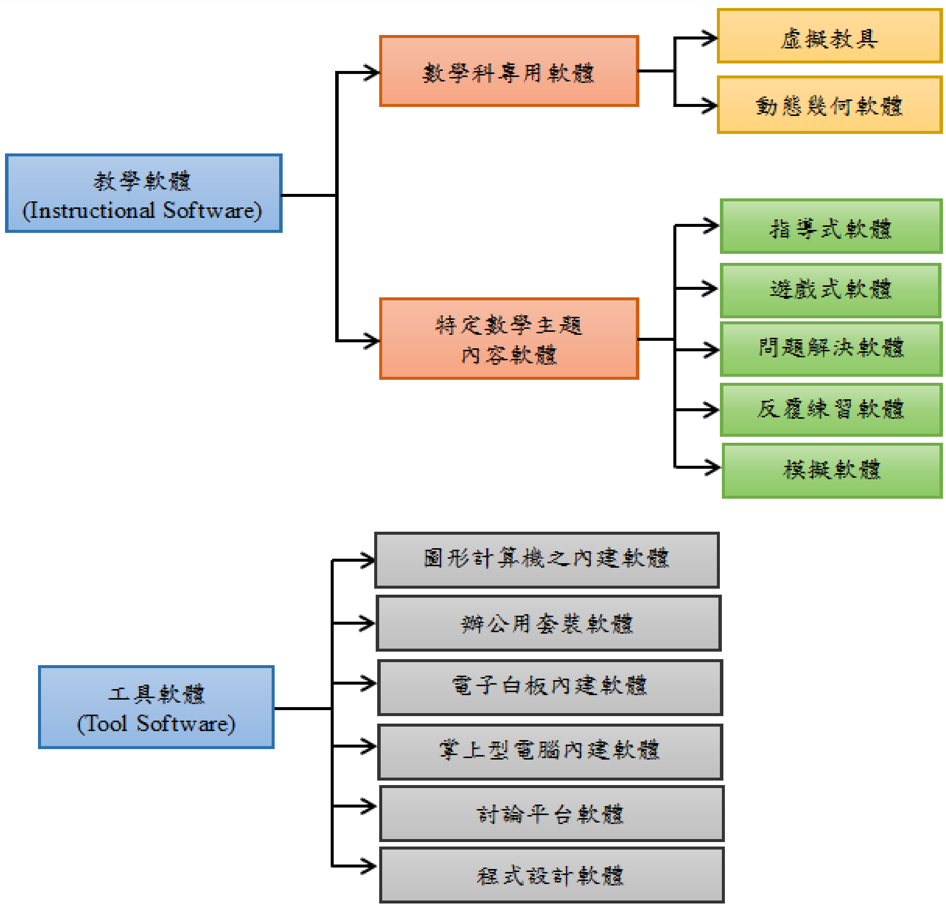
為了能更有條理地彙整軟體工具種類，本研究採用 Roblyer & Doering（2010）所提的方式作為分類依據，將軟體科技工具分成兩大類，一類為工具軟體（Tool

Software），另一類為教學軟體（Instructional Software）。

工具軟體為可用在其他不同用途之軟體；教學軟體則是專門用來傳遞或是輔助學生進行主題式學習之應用軟體，故教學軟體的「唯一用途」是傳遞教學或是支援學習活動進行。然而，有部分軟體無法歸於 Roblyer & Doering（2010）的分類中，亦即不屬於工具軟體或教學軟體，但這一類軟體具有特定的教學內容，像是虛擬教具與動態幾何軟體，故本研究將之歸至教學軟體類別。因此本研究修改 Roblyer & Doering 的分類方式，保留原本的工具軟體與教學軟體兩類，再將教學軟體細分為兩個子類別，一為數學專用軟體，另為特定數學主題內容軟體。軟體的分類如圖 4-1 所示。

由圖 4-1 可知，工具軟體包括討論平台之軟體、辦公用套裝軟體、程式設計軟體、圖形計算機之內建軟體、電子白板之內建軟體以及一般掌上型電腦之內建軟體。而教學軟體分為兩類，一類為數學科專用軟體，包括動態幾何軟體與虛擬教具；另一類為特定數學主題內容軟體，包括指導式軟體、反覆練習軟體、問題解決軟體、教學遊戲軟體以及模擬軟體。

圖 4- 1 資訊科技融入數學科教學之「軟體分類」圖



然而，硬體或軟體工具不可能單獨被拿來使用，本研究繪製圖 4-2 以呈現硬體搭配軟體之使用方式，便能更清楚地了解科技工具融入教學之使用方式與情況。圖中左邊為硬體，右邊為軟體，而從硬體連出箭頭則表示硬體搭配何種軟體一起使用，例如在文獻中，桌上型電腦搭配電子白板或是投影機與數學科專用軟體一起使用；圖形計算機則與投影機、特定數學主題內容軟體搭配使用；筆記型電腦、平板電腦有搭配數學科專用軟體、特定數學主題內容軟體一起使用。圖中軟硬體名稱後面括號中的數字代表使用個數，例如桌上型電腦後面括號寫「61」，代表納入本研究全文分析之 79 篇文獻中，有 61 篇運用桌上型電腦融入數學科教學；圖形計算機後面的括號寫「11」指有 11 篇文獻運用圖形計算機融入數學科教

學；虛擬教具後面的「16」則表示有 16 篇文獻提到使用虛擬教具軟體融入數學科教學。

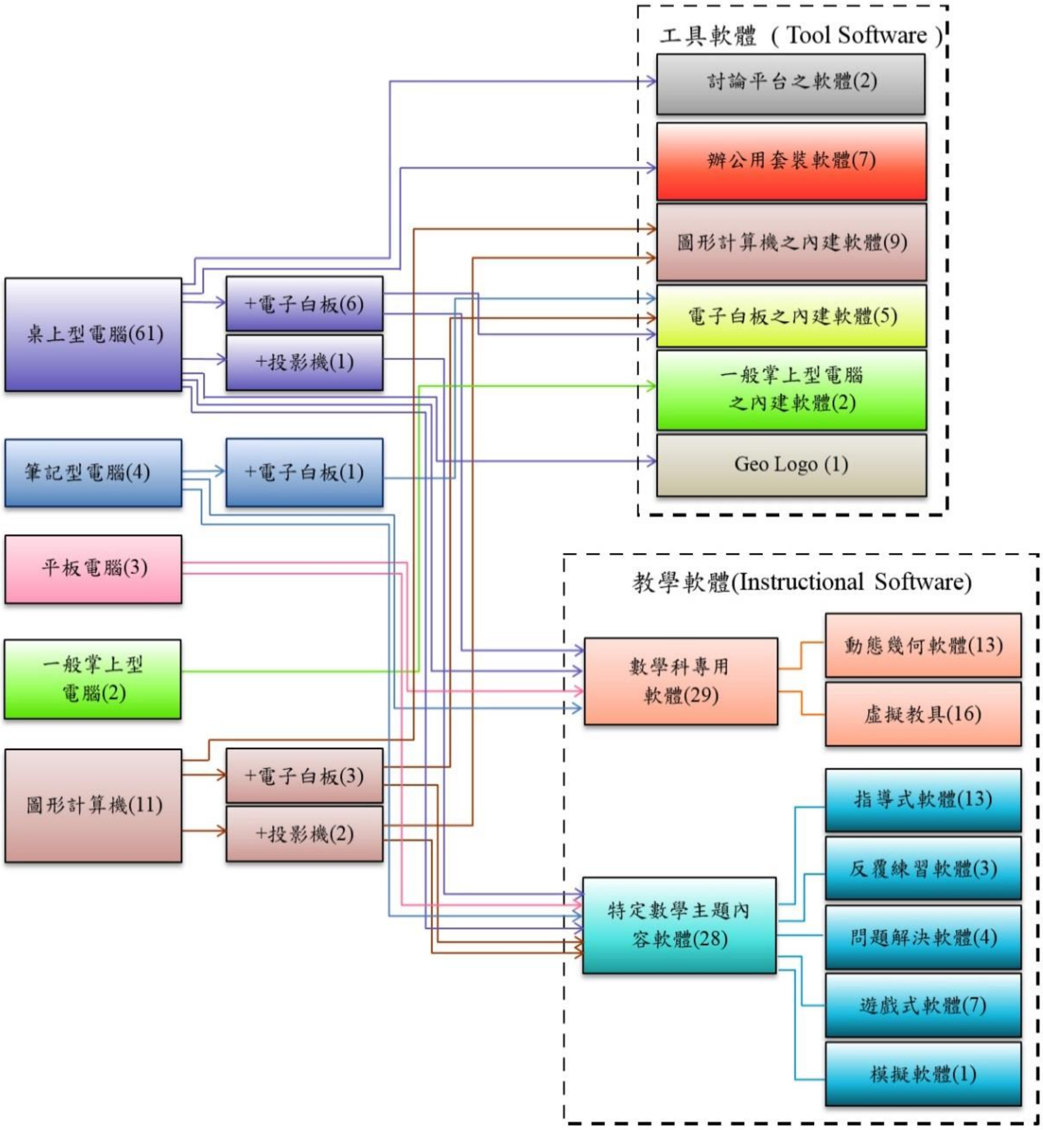


圖 4- 2 資訊科技融入數學科教學「科技工具」之關聯圖

第二節　科技工具之特性

本節將呈現資料萃取表格中「科技工具之特點」欄位彙整結果並進一步討論，說明每種科技工具獨有之特性，而此些特性是有助於學習活動之進行並且對學習

成效具有影響力。

彙整「科技工具之特點」欄位後，得知資訊科技融入中小學數學科教學之工具特性可分為兩類，一類是互動性，另一類是視覺化，以下就這兩大類進行分析與說明。在每個示例後皆有括號一組數字，代表文獻的編號，例如（168）代表這個示例出自於流水號為 168 的那篇文獻；而（灰六）則代表灰色文獻中編號 6 的文獻。

一、互動性

科技工具融入數學科教學後帶來了更多的人際互動與教材互動，並且打破傳統較為靜態的教學方式，學生不再是被動地接受教師所教授的知識，而是變成主動建構知識並學習技能的角色。以下就「人際互動」與「人機互動」說明分析結果。

(一) 人際互動

在人際互動方面，因科技工具融入後，學生更能分享自己的想法，與同儕意見不同時可立即進行溝通與討論以澄清想法，學生能方便地相互提問與評論對方的建議並給予回饋，也能以合作方式進行學習活動。學生分享、溝通、協商、討論、給予回饋以及評論他人想法，這些使得同儕之間的互動更加頻繁，提升學習成效。而互動的方式有以下幾種：

1. 分享：學生將自己的想法與作品與他人分享。

【示例】Ghosh（2004）之研究中，十年級學生使用圖形計算機學習機率概念。學生透過圖形計算機來表達自己的意見與提出問題，使學習過程更具互動性，提升學生學習成效（168）。

2. 溝通、討論、回饋及評論：同儕相互交換意見，而當同儕之間意見相左時，學生描述、澄清、證實以及反駁自我或他人想法，或是學生對同儕進行有意義的提問與回應同儕評論。

【示例】Hwang, Su, Huang & Dong（2009）之研究中，國小六年級學生使用虛

擬教具與電子白板系統學習解決幾何問題。學生使用電子白板與同儕分享想法、同儕之間反覆溝通、澄清自我的想法以及追尋更正確的答案，有助於學生解決幾何問題（4148）。

【示例】Hwang, Chen & Hsu（2006）之研究中，國小六年級學生使用電子白板學習分數除法。學生使用電子白板具備的聲音記錄器，與同儕互動與溝通，並且記錄口頭解釋，使學生易於理解同儕的解法（660）。

【示例】Tsuei（2012）之研究中，國小學生使用 Multi-User G-Math Peer Tutoring System 學習數與運算概念。學生透過同儕指導進行溝通與討論，有助於學生學習（6060）。

【示例】Yelland（2002）之研究中，國小二年級學生使用 Geo Logo 學習長度概念，在學習活動中，Geo Logo 促使學生更融入小組討論，影響學生理解長度概念（2996）。

【示例】Hwang, Su, Huang & Dong（2009）之研究中，國小六年級學生使用虛擬教具與電子白板系統學習解決幾何問題。學生使用多媒體電子白板系統來有意義地回應同儕評論以及獲得回饋（4148）。

【示例】 Hurme, & Jarvela（2005）之研究中，中學生使用網頁式學習論壇（The network-based learning environment knowledge forum）解決幾何與機率問題。各小組透過論壇呈現解題方法、同儕相互評論解法、修改解法，讓學生有機會使用數學概念與說明解法（1944）。

【示例】Zurita & Nussbaum（2004）之研究中，國小學生使用行動載具學習加法與減法運算。在學習活動中，行動載具支援學生於合作方式解題時進行協商與溝通（732）。

【示例】Lan, Sung, Tan, Lin & Chang（2010）之研究中，國小四年級學生於合作式學習發展估算技能。學生透過與同儕合作討論而能有效地使學生發展估算技能與估算策略之後設認知知識（4140）。

由上述分析結果可知，人際互動以同儕互動為主。資訊科技工具融入教學使

學生經驗較以往傳統式教學更多的動態性學習與體驗，而不再只是靜靜地坐在位置上聽教師講授課程。學生之間也因而有更多的分享、溝通與討論、協商、反思，也會針對同儕的想法或意見給予回饋或評論，這些學習改變提升學生學習成效，亦促進了學生社會化行為與發展。

(二) 人機互動

科技工具融入教學後，促使學生與學習內容互動更為頻繁，從與人機互動的過程中，易於習得並理解知識與技能，進而達到教師所給予的學習目標。人機互動包含學習情境或是學習內容或是教材互動：

1. 學習情境：學生與學習情境互動，由於科技工具提供學生之學習環境是與真實生活事件連結或是遊戲情境等，使學生更能融入於學習當中。

【示例】Yelland（2002）之研究中，國小二年級學生使用 Geo Logo 學習長度概念，此學習活動的情境與真實世界連結（2996）。

【示例】Gürbüz & Birgin（2012）之研究中，指導式軟體 Computer-assisted teaching (CAT) 中的練習活動情境為真實生活事件，此提升學生之學習動機（712）。

【示例】Tsuei（2012）之研究中，Multi-User G-Math Peer Tutoring System 提供學生遊戲般的學習情境來提升學習數與運算之學習動機（6060）。

【示例】Bai, Pan, Hirumi & Kebritchi （2012）之研究中，3-D mathematics games 提供學生於遊戲情境中學習，對學生的學習成就有正向影響（237）。

2. 學習內容或教材：促使學生與學習內容有更多的互動以提升學習動機與學習成效，為學生帶來與傳統教學不一樣的學習體驗。其包含豐富的教材庫與多次練習、可控制學習教材以配合自我學習步調等。

(1) 豐富的教材庫與多次練習：科技工具提供豐富的示例能讓學生多次練習，提升學生練習的質與量。

【示例】Moyer-Packenham & Suh（2012）之研究中，虛擬教具提供多個等值分數與異分母加法之例子，讓學生能多次練習，提升較低成就學生的學習成就

（6155）。

【示例】Gürbüz & Birgin（2012）之研究中，指導式軟體 Computer-assisted teaching（CAT）可讓國小學生多次練習，而使學生能補救錯誤的機率迷思概念（712）。

【示例】 Baki & Güveli（2008）之研究中，Web-based mathematics teaching（WBMT）提供學生豐富的例子，讓九年級學生可多次閱讀、練習以及複習學習內容，有助於學生之學習成效（671）。

【示例】Nguyen, Hsieh & Allen（2006）之研究中，Web-based assessment and practice（WP）提供學生多次練習的機會，鼓勵學生花時間於學習與提升學習成就（983）。

【示例】Nguyen & Kulm（2005）之研究中，Web-based Assisted Learning and Practice（WALA）提供中學生豐富而多樣的練習情境，使學生可多次練習，提升練習次數與品質（灰七）。

(2) 可控制自我學習步調：由於每位學生的學習節奏不一，可依自我需求或學習情況來調整或控制學習步調。

【示例】Reimer & Moyer（2005）之研究中，國小三年級學生使用虛擬教具學習分數概念。虛擬教具能讓學生依自己的學習狀況來掌控自己的學習步調，而支援學習困難學生之學習（6211）。

【示例】Steen, Brooks & Lyon（2006）之研究中，虛擬教具能讓學生依照自我需求 (self-regulate) 將學習步調做適當的調節。學生進行練習活動時，可將練習題目自行調整為適合自己程度的難度（6203）。

【示例】Guven（2012）之研究中，動態幾何軟體 Cabri 能讓中學生於學習活動中控制自己的學習步調，提升其理解能力，對學生的學習有正向影響（1358）。

【示例】Martin & Velay（2012）之研究中，由於 Computer aided design（CAD）software 內有許多圖庫（線條或是幾何圖形），國小學生能從既有圖庫中選出所

要的圖形，立即開始作圖，讓學生易於使用並做出精確的圖形（6504）。

由上述分析結果可知，學生比在一般教學中，與學習內容有更多的互動。科技工具能營造出各種真實或有趣的學習環境而使學生更加融入學習活動中，再加上科技工具提供豐富的教材庫與練習示例而讓學生能立即進行學習，學生可不斷地進行練習活動以強化學習之概念，也可依據自己的學習情況來調控自我學習步調，使學生易於完成獲達到教師給予學習目標。

二、視覺化

資訊科技工具之視覺化促進學生於學習活動中之資訊的傳遞與接收，且視覺化有助於學生對資訊的解讀，讓學生了解自己的學習情況來做修正，提升學習成效。以下就視覺化的類型來說明分析結果。視覺化包含回饋、提示、表徵以及操弄。

（一） 回饋與提示

回饋可分為立即性與非立即性，科技工具根據學生的學習動作完成後給予一個訊息，讓學生知道自己的學習情況以進行修正，或是學生於學習活動中，科技工具給予學生提示，可引導學生繼續進行學習。

【示例】Figueira-Sampaio, dos Santos & Carrijo（2009）之研究中，國小六年級學生操弄虛擬教具學習一次多項方程式之後，學生能即時看見自己解題過程中每一步驟的操弄結果，從虛擬教具給予的立即回饋加以反思解題方法，學生因而不會出現錯誤的解題方式（3079）。

【示例】Reimer & Moyer（2005）之研究中，虛擬教具提供學生立即回饋與特定回饋（Immediate and specific feedback），具校正與強調錯誤之功能，使學生警覺自己的迷思概念（6211）。

【示例】Guven（2012）之研究中，中學生藉由操弄幾何物件學習幾何概念，動態幾何軟體 Cabri 給予立即回饋，學生從回饋中得知操弄結果，知道有錯誤則進行討論與修正（1358）。

【示例】Chen, Looi, Lin, Shao & Chan（2012）之研究中，遊戲軟體 Collaborative Cross Number Puzzle Game 提供學生回饋機制。學生從回饋中可知答案是否正確，若答案正確，則給予簡單的重點描述，若答案錯誤，則給予提示（2843）。

【示例】Nguyen & Kulm（2005）之研究中，Web-based Assisted Learning and Practice （WALA）提供中學生立即回饋，學生可從回饋與引導得知答案是否正確，此鼓勵學生檢驗自己的錯誤並進行修正（灰七）。

【示例】Suh & Moyer（2007）之研究中，虛擬教具給予國小六年級學生解題提示，一步一步引導學生解決方程式（6106）。

【示例】Jones（2000）之研究中，動態幾何軟體提供視覺提示給中學學生，讓學生調整與分析幾何結構（1229）。

【示例】Tsuei（2012）之研究中，Multi-User G-Math Peer Tutoring System 提供學生解決數與運算之引導句子，提升學生輸入答案速度，減少錯誤發生率（6060）。

【示例】Baki & Güveli（2008）之研究中，Web-based mathematics teaching（WBMT）提供學生解題之引導提示。以範例一步一步解說過程，使學生可清楚地了解每一步驟，有助於改善學生學習態度與自信心，幫助學生學習（671）。

（二） 數學表徵之呈現

科技工具呈現數學表徵，例如數值、圖像、表格以及數學符號等，將抽象的數學概念具體化。而不同的表徵之間可以用動態方式連結或轉換，使學生更加容易習得與理解概念。

【示例】Tabach & Friedlander （2008）之研究中，Spreadsheets 所呈現的符號表徵，使方程式之等式的表示式更加具體且有意義，提升學生抽象符號學習（1959）。

【示例】McLeod, Vasinda & Dondlinger（2012）之研究中，國小六年級學生使用虛擬教具學習比例概念，虛擬教具將抽象的數學概念視覺化，有助於學生有更深之理解（6098）。

【示例】Suh & Moyer（2007）之研究中，虛擬教具使國小三年級代數之多重表徵連結 (視覺模式與符號表徵模式之清楚連結) ，動態視覺影像提升學生用圖形表徵表達自己的想法與解說能力（6106）。

【示例】Suh（2010）之研究中，虛擬教具呈現統計圖形表徵，不同的箱形圖幫助學生學習更複雜的數學概念與進行更深層的統計資料分析（6155）。

【示例】Reimer & Moyer（2005）之研究中，虛擬教具提供學生多重表徵，其包含文字、圖像、以及數字等，其提升學生概念學習（6211）。

【示例】Stohl & Tarr（2002）之研究中，模擬軟體 Probability Explorer software 提供學生視覺化表徵，有助於學生分析資料（灰八）。

（三） 操弄

學生透過操弄科技工具所提供的數學物件，從科技工具給予的視覺呈現中，來觀察動態的改變、修正錯誤、檢驗或測驗假設等等。

【示例】Hauptman（2010）之研究中，指導式軟體 Virtual Spaces 1.0software 讓學生操弄空間圖像再加上自我調節問題，有效改善學生口語與非口語的空間思考學習成效（669）。

【示例】Kordaki（2003）之研究中，指導式軟體 The ‘Conservation of Area and its Measurement’ (C.AR.ME.) Microworld 使學生操弄幾何圖形時會自動轉換視角，此動態方式幫助學生探討面積概念（1252）。

【示例】Oguz & Abdullah（2012）之研究中，動態幾何軟體 Cabri 呈現學生拖拉之方程式的圖形，拖拉形狀之特性使學生發現動態改變，藉由圖形或符號表徵提供有意義的關係，有助於學生理解數學概念（2333）。

【示例】Santos-Trigo（2004）之研究中，學生操弄動態幾何軟體產生圖形以檢驗特性，探索長度，面積，周長之關係（6208）。

【示例】Suh, Moyer & Heo (2005) 之研究中，虛擬教具讓學生透過操弄數學物件，這些物件的顏色、圖像以及動態呈現操弄過程，抓住並維持學生注意力，使

學生更能融入學習活動中（3505）。

【示例】McLeod, Vasinda & Dondlinger（2012）之研究中，國小六年級學生於操弄虛擬教具過程中，看見操弄之改變過程，有助於學生測試假設，並依據立即回饋修改錯誤之概念（6098）。

由上述分析結果可知，科技工具視覺化之特性提供學生回饋協助學生覺察他們推理的合理性，以調整其思維，有效於促進學生意義化的思考（Ploger, Klingler & Rooney, 1997；Kirschner & Erkens, 2006）。而且，即時性的回饋使學生更能反省、討論以及溝通解題的行動（Figueira-Sampaio, dos Santos & Carrijo, 2009）。當學生於學習過程中有了困惑時，此時科技工具會給予學生一些提示來引導並解其不懂之處，使其能繼續進行學習。科技工具呈現各種數學表徵，像是數值、數學符號或是圖表，使學生能將不同的表徵做連結，將抽象概念具體化，以利其理解。此外，科技工具讓學生實際地體驗操弄各式各樣數學物件，以動態方式呈現操弄過程與結果，使學生能觀察整個變化過程，以驗證並澄清其想法，進而將錯誤觀念或迷思修正。因此，科技工具之視覺化特性對於學生數學之學習是相當有幫助的。

第三節　　科技工具、學習活動與認知層次之關係

本節呈現資料萃取表格之「學習活動」欄位彙整結果並進一步討論，說明科技工具融入數學科之學習活動後，能提升學生之認知層次。學習活動分類是依據Krathwohl（2002）所修訂的布魯姆（Benjamin S. Bloom）認知領域教育目標之認知過程版本。

圖 4-3 呈現硬體搭配軟體融入學習活動後，能促使學生所學以提升到哪一個認知層次。由圖 4-3 可知，學生於學習活動過程中使用科技工具後，認知層次上的培養或提升主要是以理解為主，其次是應用與記憶；分析層次最少，而創造層次則完全沒有。分析結果之說明是以軟體為主，硬體為輔，兩者搭配融入方式，

論述每一種搭配情況。

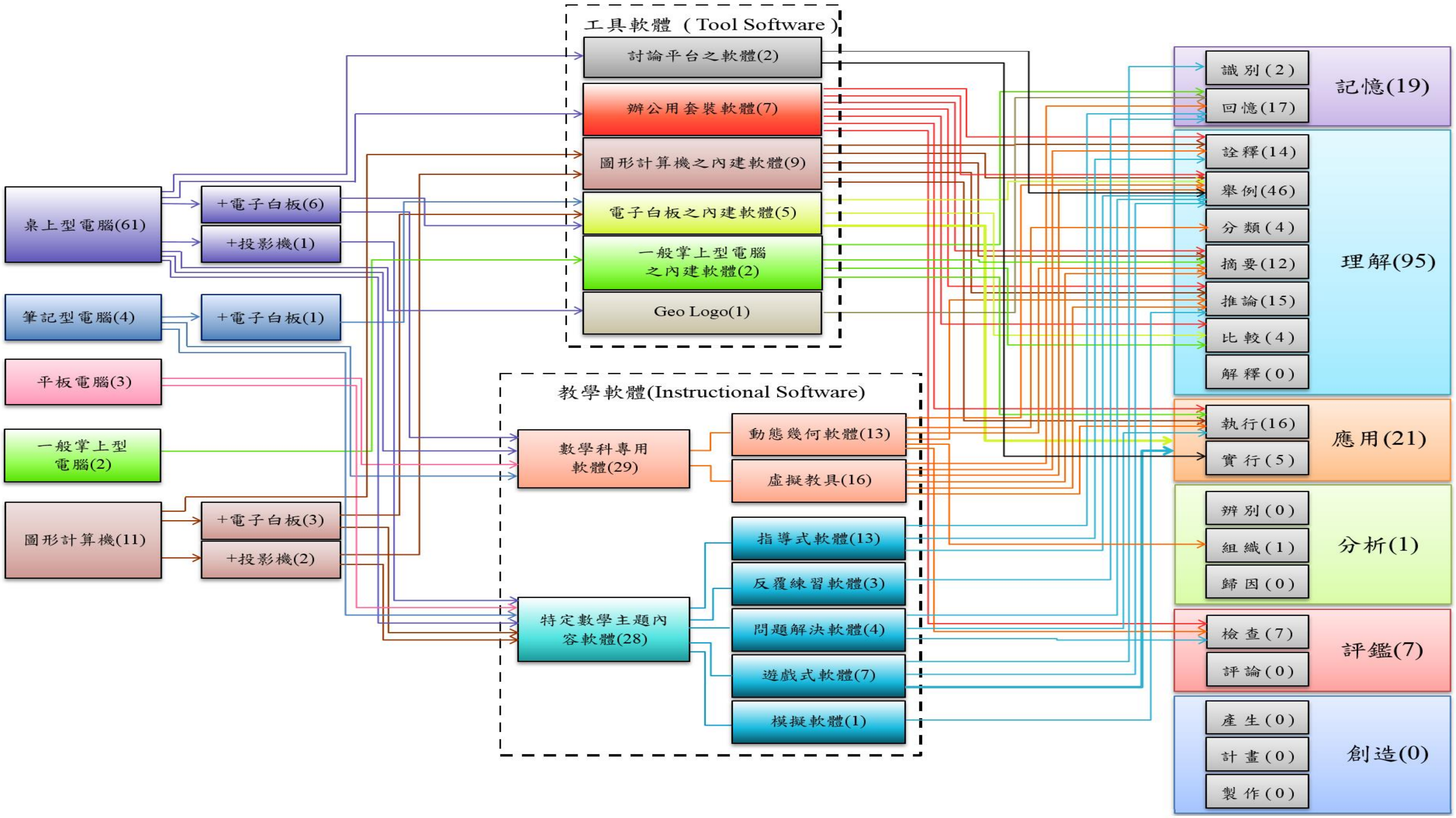


圖 4-3 資訊科技融入數學科教學之學習活動與認知過程之關係

如第四章第一節所述，資訊科技融入數學科教學之軟體分為工具軟體與教學軟體兩大類，以下針對此兩類依序說明。

一、工具軟體

圖 4-4 呈現工具軟體融入數學科教學之學習活動可達到的認知層次。從圖 4-4 可以清楚知道每一種工具軟體融入後，能使學生於學習活動中達到那些認知層次，以下說明每一種工具軟體融入後之情形。

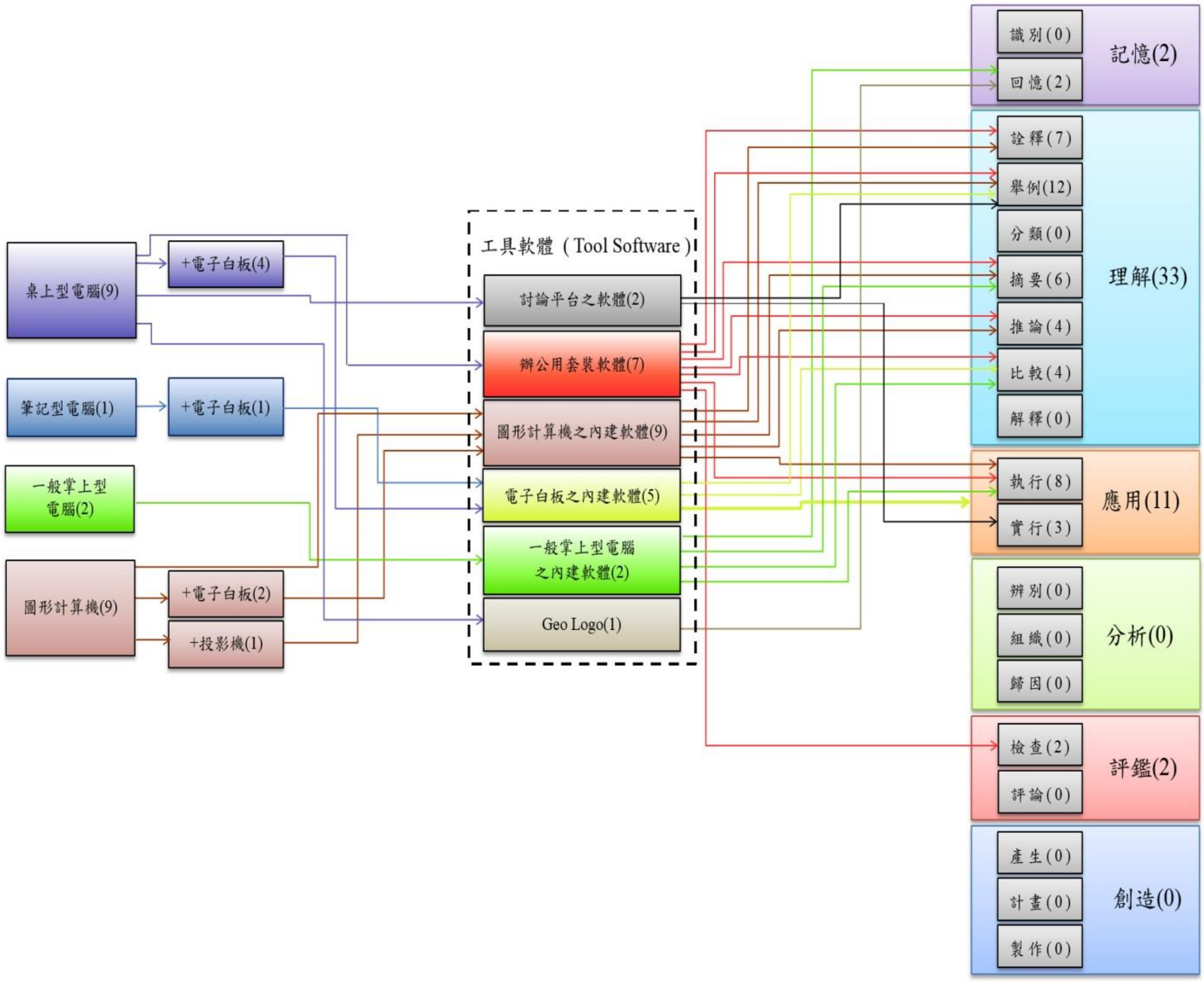


圖 4- 4 資訊科技融入數學科教學之工具軟體與認知過程之關係圖

（一） 討論平台之軟體

討論平台之軟體搭配桌上型電腦使用。當其融入學習活動後，學生使用討論平台之軟體可以提升認知中的理解與應用層次，而理解部分包含舉例；應用部分則包含實行。

1. 理解

(1) 舉例：學生使用一般性概念或是原則性知識來建構幾何圖形、數值表徵、線性圖形以及極限，探討多邊形之定義、平面圖形與立體圖形之性質以及多項式之極限定義，運用性質或定義創造示例。

【示例】Hurme & Jarvela（2005）之研究中，中學生使用問題解決軟體學習多邊形之定義。學生探討多邊形，找出多邊形之定義，使用公式計算多邊形面積，以及使用定義創造多邊形之示例或問題（1944）。

2. 應用

(1) 實行：學生討論估算問題之解決方法，將解法列出來，學生針對同儕的解題方法進行討論並提出看法與建議，企圖找出更好的解題策略。

【示例】Lan 等人（2010）之研究中，國小四年級學生使用問題解決軟體學習估算策略。學生以合作方式解決估算問題，分享並呈現解法，全班針對解法進行討論並選出最好的解題策略（4140）。

（二） 辦公用套裝軟體

辦公用套裝軟體包含 PowerPoint、Excel、Spreadsheets，通常搭配桌上型電腦使用。當其融入學習活動，學生使用辦公用套裝軟體後可以提升認知中的理解、應用以及評鑑層次。在理解部分包含詮釋、舉例、摘要、推論以及比較等五個認知次項目；在應用部分包含執行這個認知次項目；在評鑑部分包含檢查這個認知次項目。

1. 理解

(1) 詮釋：學生使用辦公用套裝軟體進行數學之各種表徵轉換，包含數值、圖表、符號等，學生操弄這些數學表徵，學習數學等式之概念或是不同表徵之間連結關係，將抽象概念具體化，使之能更容易理解並學習。

【示例】Aktas, Bulut & Yuksel （2011）之研究中，八年級學生使用 Microsoft Power Point 呈現不同的數學表徵，學生將數學例子用三種數學

表徵，包含圖形、數列以及表格呈現（6780）。

【示例】Tabach & Friedlander（2008）之研究中，國中生使用 Spreadsheet 軟體學習代數方程式。學生將給予的數字填入 spreadsheet 欄位，使用 Spreadsheet 方程式功能進行運算。學生創造欄位與做運算，用符號表徵來表示等號兩邊的算式要相等（1959）。

(2) 舉例：學生使用辦公用套裝軟體習得統計圖形之特性。

【示例】Wu & Wong（2007）之研究中，中學生使用 Excel 學習長條圖的垂直軸刻度不從零開始之特性，學生透過輸入不同的最大值與最小值，以找出適當的垂直軸刻度，並從輸入各種數值得知此特性（6140）。

(3) 摘要：學生使用辦公用套裝軟體將給予的代數資訊用來建構或發展相關代數圖表，以理解並學習方程式。

【示例】Topcu（2011）之研究中，10 年級學生使用 Spreadsheets 學習二次函數作圖與相關問題。學生將教師給予的代數問題資料輸入至 Spreadsheets 欄位以建構問題之相關表格與方程式圖形（6538）。

(4) 推論：學生使用辦公用套裝軟體從圖形找出特性並推論出關係。

【示例】Kramarski & Ritkof（2002）之研究中，九年級學生使 Excel 學習圖形推論。學生從 Excel 所呈現的圖形，推論出適當的方程式圖形，運用質與量方法解釋方程式圖形，並從方程式圖形做結論（2834）。

【示例】Tabach, Hershkowitz & Arcavi（2008）之研究中，七年級學生使用 Spreadsheets 學習方程式表示式。學生使用 Spreadsheets 探索方程式之遞迴關係，並使用拖拉功能取得數字與圖形表徵（灰五）。

(5) 比較：學生使用辦公用套裝軟體判斷統計線性圖與統計圖像面積問題，學生根據給予的比較項目，判斷一系列的圖形是否正確或是找出圖形相同處與不同處。

【示例】Wu & Wong（2007）之研究中，中學生使用 Excel 學習判斷統計相關圖形，例如長條圖、累積線性圖。學生從兩個統計之線性圖，比較

並判斷兩個線性圖之相同與不同之處。此外，還給予學生一個標準圖像與多個統計圖像，學生將多個圖像與標準圖像進行比較並判斷是否正確（6140）。

2. 應用

(1) 執行：學生使用辦公用套裝軟體來練習解線性方程式問題。

【示例】Kramarski & Gutman（2006）之研究中，九年級學生使用 Excel 練習解線性方程式題目。兩人一組，練習解題之題目類似教科書上的題目，學生將解法透過 E-mail 寄給教師（688）。

3. 評鑑

(1) 檢查：學生使用辦公用套裝軟體進行假設之測驗與探索，以結果來檢驗代數式子是否正確。

【示例】Tabach & Friedlander（2008）之研究中，國中生使用 Spreadsheets 軟體學習代數方程式。學生使用數值與符號以產生代數表示式，並且運用此等式來測驗自己的假設（1959）。

【示例】Tabach, Hershkowitz & Arcavi（2008）之研究中，七年級學生使用 Spreadsheets 學習方程式表示式。學生使用 spreadsheets 進行方程式之假設並檢驗是否正確（灰五）。

（三） 圖形計算機之內建軟體

圖形計算機包含 Casio CFX 9850 GB PLUS、TI-82 or TI-83Plus、Hewlett Packard HP39G、TI-Navigator 3.0、$TI-Nspire^{TM}$等等。其融入學習活動後，學生使用圖形計算機可以提升認知中的理解與應用層次。而在理解部分包含詮釋、舉例、摘要以及推論等四個認知次項目；在應用部分包含執行這個認知次項目。

1. 理解

(1) 詮釋：學生將代數與統計資料進行多種表徵之間轉換，包含方程式、數值以及圖表等等。

【示例】Brown（2004）之研究中，十一年級與十二年級學生使用圖形計算機學習方程式圖形。學生以合作方式根據給予的三次函數來畫出完整的函數圖形（157）。

【示例】Graham & Smith（2004）之研究中，國小五年級學生使用圖形計算機學習乘法。學生將遊戲所產生的統計資料轉換成問題表格之形式（769）。

(2) 舉例：學生能找出並根據統計與方程式之概念及特徵，建構表徵示例，例如方程式、箱形圖、運算表格或嘗試操弄不同代數參數，找出公式或定義。

【示例】Abu-Naja（2008）之研究中，九年級學生使用圖形計算機學習方程式概念與方程式圖形。學生畫出方程式的圖、找出方程式為零的點、決定方程式正值與負值的範圍（1303）。

【示例】Ghosh（2004)之研究中，十年級學生使用圖形計算機 Casio CFX 9850 GB Plus 學習機率概念。教師給學生每人一張學習單，其用逐步方式解釋概念：機率的基本定義與隨機的意義、隨機試驗與樣本空間、一個事件的機率、事件之理論機率 V.S 經驗機率。學生運用圖形計算機模擬一個擲硬幣實驗來探索概念並記錄觀察結果（168）。

(3) 摘要：學生根據呈現之資訊，建構統計相關圖形。

【示例】Forster（2007）之研究中，十二年級學生使用圖形計算機搭配抽樣軟體學習統計之箱型圖。學生繪出給予資料之點狀圖，將點平均分給四小組，且使用圖形計算機來決定敘述統計量（1873）。

(4) 推論：學生從代數表徵中找出並推論其關係。

【示例】Doerr & Zangor（2000）之研究中，中學生使用圖形計算機 TI-82 或 TI-83 學習微積分。學生創造量化系統，在習得經驗後，描述與解釋方程式圖與結構以及預測方程式圖形。推論資料、找出資料有意義的表徵（表格、圖形、方程式）與歸納關係（1189）。

【示例】Leng（2011）之研究中，中學生使用圖形計算機$TI - Nspire^{TM}$學習微積分。學生先檢視被給予的問題或是將參數輸入至圖形計算機，操弄模擬參數，要求學生用公式推測、檢驗、證實推測，最後推導出公式、歸納結果、總結概念（2615）。

2. 應用

(1) 執行：學生依解題程序，解決代數與統計之問題。

【示例】Tajudin 等人（2007）之研究中，中學生使用圖形計算機解直線問題。教師使用圖形計算機解說直線概念後，學生使用圖形計算機進行解直線問題（灰二）。

【示例】Brown（2004）之研究中，十一年級與十二年級學生使用圖形計算機解方程式題目並將過程記錄下來。學生一開始先放大函數圖形，看見方程式全圖後開始討論與調整方程式之最大值與最小值，檢驗是否正確。學生觀察圖形計算機畫面，當學生不確定輸入點是否正確時，可從圖形計算機畫面中方程式圖形的變化得知（157）。

（四） 電子白板之內建軟體

電子白板通常搭配筆記型電腦、圖形計算機以及桌上型電腦等硬體使用。其中，最常搭配的是桌上型電腦，而與筆記型電腦、圖形計算機搭配使用時，被用以投影圖形計算機之螢幕畫面，或是提供操弄媒介。當其融入學習活動後，學生使用電子白板可以提升認知中的應用層次。而在應用部分包含執行與實行等兩個認知次項目。

1. 應用

(1) 執行：電子白板呈現題目與答案，學生從中選取答案，並說明選擇此答案之原因。

【示例】Hwang, Chen & Hsu（2006）之研究中，國小六年級學生使用電子白板解決分數除法問題。電子白板系統提供題目與答案選項，學生從

中選取答案並說明原因（660）。

(2) 實行：學生於電子白板上討論數值運算與幾何問題，了解題意、思考解題方法並找出正確答案。學生於電子白板上評論同儕之數值運算與幾何問題之解題方法，並且回應同儕給予的意見與建議。

【示例】Hwang, Su, Huang & Dong（2009）之研究中，國小六年級生使用電子白板進行幾何之解題，教師使用虛擬教具之電子白板系統佈題，學生於虛擬教具之電子白板系統解題、討論解法並呈現解法，同儕針對解法提出評論（4148）。

【示例】Hwang, Chen, Dung & Yang（2007）之研究中，國小六年級學生使用電子白板解決數值運算與幾何問題、說明解法以及回應同儕之評論（6506）。

（五） 掌上型電腦之內建軟體

掌上型電腦包含 Compaq iPAQ 與 HP 的 iPAQ，其具有內建軟體，或可操作其他軟體使用，像是特定主題內容軟體。當其融入學習活動後，學生使用一般掌上型電腦可以提升認知中的記憶、理解以及應用層次，而記憶部分包含回憶這個認知次項目；理解部分包含比較這個認知次項目；應用部分則包含執行這個認知次項目。

1. 記憶

(1) 回憶：從掌上型電腦內建之軟體給予的提示，選擇正確答案。

【示例】Roschelleetal（2010）之研究中，國小四年級學生使用掌上型電腦學習分數。掌上型電腦呈現多選題之題目，學生從中選取答案，學生做答完後，掌上型電腦給回饋，讓學生知道是否選對。若選錯答案，則進行小組討論，掌上型電腦會給予學生提示，直到學生選對答案為止（1383）。

2. 理解

(1) 比較：學生將分數的兩種表徵（數值與圓餅圖）做比較與配對，並討論配對是否正確。

【示例】Roschelleetal（2010）之研究中，國小四年級學生使用掌上型電腦學習分數。學生的掌上型電腦收到分數的兩種表徵，有數值與圓餅圖，學生將此兩種表徵進行比較與配對，小組討論表徵配對是否正確。學生透過掌上型電腦將答案送出，掌上型電腦會給予學生回饋，告知學生是否正確，若答案是不正確的則學生繼續討論，直到分數表徵之配對正確為止（1383）。

3. 應用

(1) 執行：學生使用掌上型電腦來練習解決數值運算問題，像是加法與減法。

【示例】Zurita & Nussbaum（2004）之研究中，國小學生使用行動載具解加法與減法運算問題。進行學習活動時，給每組學生一系列的學習目標，學生進行解題活動，組員可藉由行動載具相互傳送學習資訊以完成解題（732）。

（六） 程式設計軟體

程式設計軟體搭配桌上型電腦使用。當其融入學習活動後，學生使用 Geo Logo 可以提升認知中的記憶層次，而記憶包含回憶這個認知次項目。

1. 記憶

(1) 回憶：學生依據給予的程式指令，回憶指令的涵義，使小烏龜依據指令移動相等之步伐，習得長度概念。

【示例】Yelland（2002）之研究中，國小二年級學生使用 Geo Logo 進行長度概念學習。學生兩人一組，依據教師提供的指令使 Geo Logo 中的小烏龜產生等長或不同長度之移動步伐大小以抵達目的地（2996）。

由上述分析結果可知，工具軟體於認知層次上的提升包含記憶、理解、應用以及評鑑，其中又以理解層次中的舉例為主，其次為應用中的執行，與理解中的

詮釋；而記憶與評鑑層次最少，創造則無。

二、教學軟體

圖 4-5 呈現教學軟體融入數學科教學之學習活動可達到的認知層次。從圖 4-5 可以清楚知道每一種教學軟體融入後，能使學生於學習活動中達到那些認知層次，而教學軟體分為數學科專用軟體與特定數學主題內容軟體之兩大項，以下說明每一種教學軟體融入後之情形。

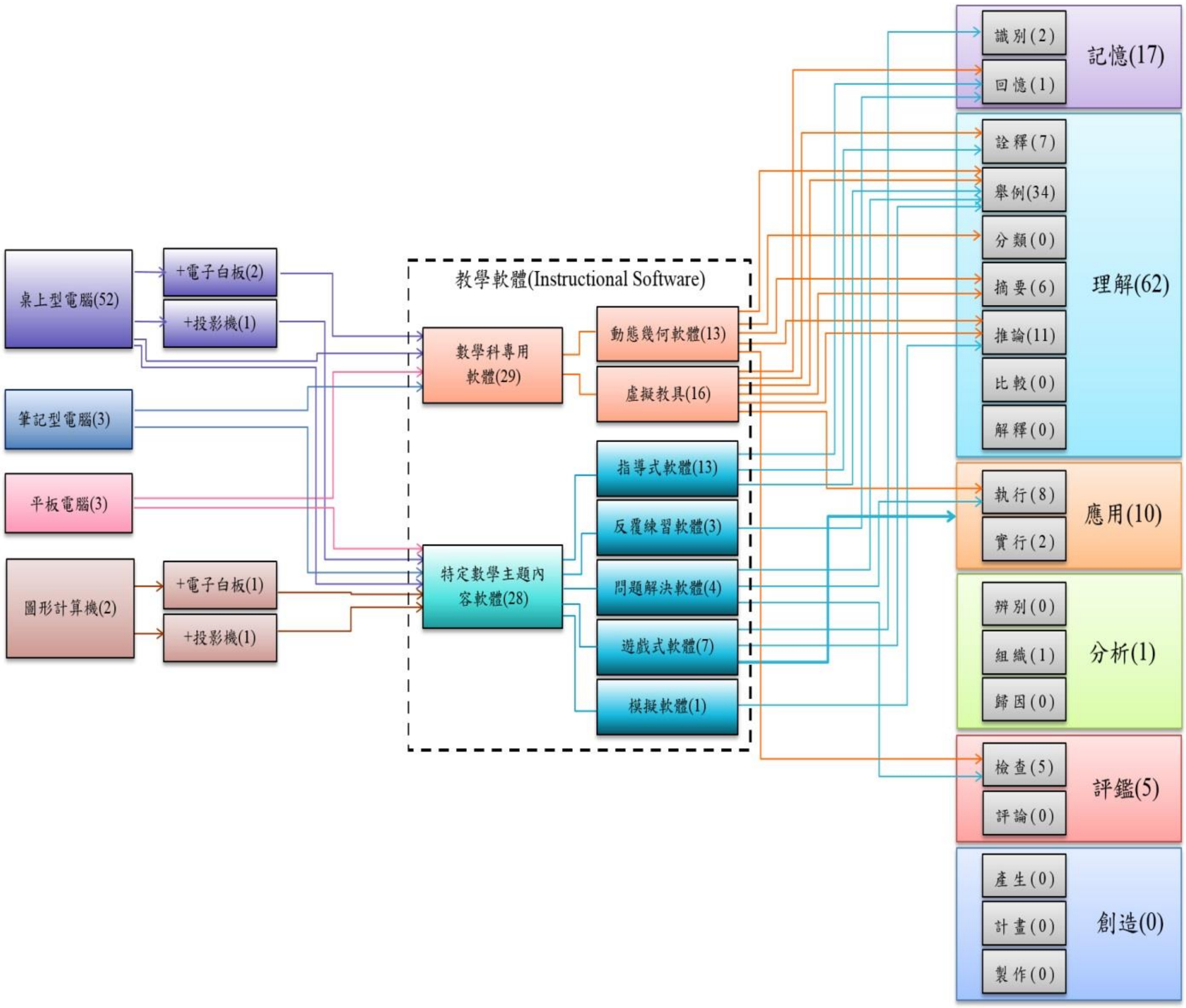


圖 4- 5 資訊科技融入數學科教學之教學軟體與認知過程之關係圖

(一) 數學科專用軟體

科目專用軟體通常搭配筆記型電腦、平板電腦以及桌上型電腦等硬體使用。最常搭配的是桌上型電腦，而與電子白板和投影機搭配使用時，是被用以展示操

作之螢幕畫面或是操作之媒介。

1. 動態幾何軟體

動態幾何軟體包含 Geometer’s Sketchpad、Cabri 以及 GeoGebra 等等。當其融入學習活動後，學生使用動態幾何軟體可以提升認知中的理解、分析以及評鑑層次。而理解部分包含舉例、分類、摘要以及推論等五個認知次項目；而分析部分包含組織這個次項目；而評鑑部分包含檢查這個次項目。

(1) 理解

(i) 舉例：學生依據幾何與代數之方程式概念或定義之特徵，建構相關示例。

【示例】Erbas & Yenmez（2011）之研究中，國小六年級學生使用動態幾何軟體 Geometer’s Sketchpad 學習幾何圖形之特性。學生在動態幾何學習環境下進行探索式活動，藉由量測、探索、操弄以及表徵轉換幾何物件以發現幾何形狀的特性，並且完成學習單上指定的學習活動與記錄結果（708）。

【示例】Guven（2012）之研究中，中學生使用動態幾何軟體 Cabri 學習幾何圖形轉換之特性。學生一人一機，使用 Cabri 軟體完成學習單。學生根據學習單上的教學使用 Cabri 軟體逐步建構幾何的轉換，透過拖拉幾何物件動態地觀察幾何圖形的轉換，探索轉換之特性、驗證探索以及解釋（1358）。

【示例】Wei & Ismail（2010）之研究中，中學生使用動態幾何軟體 GeoGebra 學習幾何、代數以及統計概念。學生使用 GeoGebra 建構線性方程式與調查線性方程式特性，創造二次函數圖並探究二次函數特性（190）。

【示例】Jones（2000）之研究中，高中生使用動態幾何軟體 Cabri 學習幾何中四邊形特性。學生兩人一組使用一台電腦進行學習活動，透過一系列學習活動，學生需建構四邊形：菱形、正方形以及一個箏形。每一個學習活動包含視覺提示和建構圖形，在拖拉圖形不變之情況下，解釋

四邊形之特性（1229）。

(ii) 分類：學生運用代數與幾何概念，檢視幾何圖形（三角形、四邊形等）與方程式圖形之特性或性質。

【示例】Biza（2011）之研究中，十二年級學生使用動態幾何軟體 EucliDraw（Dynamic Geometry Software with Function Grapher Tools）學習圓之特性。學生以小組方式進行學習活動，使用 Eucli Draw 軟體檢驗圓切線之一般特性、半圓之一般特性，並將記錄於學習單上，進行全班討論（5783）。

【示例】Wei & Ismail（2010）之研究中，中學生使用動態幾何軟體 GeoGebra 學習幾何、代數以及統計概念。學生使用 GeoGebra 畫出兩圓切線並檢查兩圓切線性質（190）。

(iii) 摘要：學生根據給予的學習資訊，建構幾何及方程式圖形。

【示例】 Koklu & Topcu（2012）之研究中，十年級學生使用動態幾何軟體 Cabri 學習二次方程式之解與二次方程式之不等式。教師先教導學生操作 Cabri 軟體，特別是畫方程式圖、分析坐標平面上的點、使用拖拉功能特性。教師使用 Cabri 軟體在白板上進行講課，學生使用 Cabri 軟體練習建構二次方程式相關圖形與二次方程式之不等式並且進行討論（2333）。

(iv) 推論：學生從不同幾何形狀來推論出它們之間存在何種關係並找出具備的屬性。

【示例】Jones（2000）之研究中，高中生使用動態幾何軟體 Cabri 學習幾何圖形中四邊形特性。學生兩人一組使用一台電腦進行學習活動，學生透過一系列學習活動，探討各種四邊形之間的關係。學生透過視覺提示，此學習活動要求學生完成一個非四邊形家族類且解釋其關係為何（1229）。

【示例】Healy & Hoyles（2001）之研究中，中學生使用動態幾何軟體 Cabri 學習解決幾何問題。教師並非採用直接教學方式，而是讓學生以探索方式學習，教師扮演協助者與促進者之角色。學生使用 Cabri 建構幾何

圖形，確認並描述幾何圖形特性與關係，產生推測並針對幾何圖形特性之推測做測驗與解說原因。學生建構平行線、垂直線以及角平分線，拖曳幾何物件，探索四邊形，然後實驗、推測、解說以及將解說轉換成邏輯演繹。學習活動中還給學生一個不熟悉的四邊形之屬性，學生須運用所學，將此四邊形建構出來並找出其他屬性（灰四）。

(2) 分析

(i) 組織：學生使用動態幾何軟體看見幾何圖形結構，加入幾何結構之元素，了解其組織方式。

【示例】Santos-Trigo（2004）之研究中，高中生使用動態幾何軟體學習幾何圖形結構。學生以小組方式進行學習活動，每一組使用動態幾何軟體來辨識一個特定的曲面圖，新增曲面之元素到原始的結構中，並將建構後的曲面圖呈現給全班看，最後提出論點以支持自己的推測（6208）。

(3) 評鑑

(i) 檢查：學生檢驗並說明幾何相關問題（例如：等面積）的解決步驟、策略以及推測是否正確，此外，還有驗證代數（曲線）之假設。

【示例】Kordaki & Balomenou（2006）之研究中，中學生使用動態幾何軟體 Cabri 學習幾何問題中等面積三角形之概念。學生三人為一組，以合作方式或是獨自完成學習活動。學生以合作方式使用 Cabri 以許多方法建構一對相等的三角形、證明自己的解法策略並說明原因。此外，學生也獨自使用 Cabri 來建構三角形與另一個等面積的三角形、證明與說明自己的解決策略並且思考如何用其他方式產生與原來等面積的三角形（1911）。

【示例】M arrades & Gutiérrez（2000）之研究中，中學生使用動態幾何軟體 Cabri 學習幾何概念。學生以小組方式進行解題活動，教師觀察各小組學習情況並回答學生問題。學生創造與探索幾何圖形，產生並檢驗推測，證明其推測。最後，每一組學生將結果記錄在學習單上並儲存幾何圖形的檔案（1228）。

2. 虛擬教具

當其融入學習活動後，學生使用虛擬教具可以提升認知中的記憶、理解以及應用層次。記憶部分包含回憶這個認知次項目；理解部分包含詮釋、舉例、摘要以及推論等四個認知次項目；而應用部分包含執行這個認知次項目。

(1) 記憶

(i) 回憶：學生依照老師示範之方法，練習等值分數與異分母之加法以及幾何題目，強化習得之概念。

【示例】Steen, Brooks & Lyon（2006）之研究中，國小學生使用虛擬教具學習幾何。學生於教師教學完後使用虛擬教具進行練習，練習題目為教科書之題目，強化甫習得之幾何概念（6203）。

【示例】Moyer-Packenham & Suh（2012）之研究中，國小五年級學生使用虛擬教具學習等值分數與異分母分數加法。教師介紹數學概念與教導學生如何使用虛擬教具。教師給學生學習單，讓學生獨自使用虛擬教具進行練習（6155）。

【示例】Bolyard & Moyer-Packenham（2012）之研究中，國小六年級學生使用虛擬教具學習整數加法與減法。教師教授完整數加、減法後，學生使用虛擬教具進行練習（6158）。

(2) 理解

(i) 詮釋：學生進行多種表徵之轉換，包含文字、數值、符號以及圖表，習得加法與減法、分數、比例以及代數之概念。

【示例】Suh & Moyer（2007）之研究中，國小三年級學生使用虛擬教具學習代數方程式。學生操弄虛擬教具將虛擬天秤呈現的代數關係以方程式表示式呈現，以表示虛擬天秤左右邊所呈現之關係（6106）。

【示例】McLeod, Vasinda & Dondlinger（2012）之研究中，國小六年級學生使用虛擬教具學習比率與比例概念。虛擬教具給學生提示，用以建構一個比率之表徵。學生用另一種表徵表示百分比、小數以及等值分數（6098）。

(ii) 舉例：學生能找出等值分數概念與特徵、百分比之特性，建構百分比之圖形表徵，並使用這些特徵完成指定問題。

【示例】Burns & Hamm（2011）之研究中。國小三年級學生使用虛擬教具學習等值分數概念。學生使用虛擬教具將分數重新命名，將一個分數之等值分數，用不同分母列舉出來，而虛擬教具對於學生的操弄給予立即性回饋（4662）。

【示例】Kong & Kwok（2005）之研究中，國小四年級學生使用虛擬教具學習分數加法與減法。學生觀察虛擬教具呈現分數之符號與圖像表徵來發現其特性。接著，學生使用圖形表徵呈現分數，以發展並習得分數概念，例如：分數加法與減法程序性知識概念、等值分數概念、真分數與假分數概念以及分數借位概念（灰三）。

【示例】McLeod, Vasinda & Dondlinger（2012）之研究中，國小六年級學生使用虛擬教具學習比率與比例概念。學生使用虛擬教具來建構特定的百分比之表徵，虛擬教具對於學生所建構之圖形表徵給予回饋，且虛擬教具提供學生隨機的小數讓學生來建構圖形表徵（6098）。

(iii) 摘要：學生根據給予資訊，建構各種幾何圖形或繪製分數圖。

【示例】Lin, Shao, Wong, Li & Niramitranon（2011）之研究中，國小六年級生使用 virtual Tangram puzzle 學習幾何。每一組學生運用虛擬七巧板製作出一個漏斗的幾何圖案，教師適時給予協助，最後小組與全班分享並說明原因，教師給予學生回饋。之後，每一組再以合作方式運用虛擬七巧板練習拼湊出帆船的圖形，完成後與其他組分享並進行同儕評鑑（980）。

(iv) 推論：學生從箱形圖或長條圖顯示資料，推論統計結果。透過擴分概念，推論當分數為不同分母時其分子為何。

【示例】Yang & Tsai（2010）之研究中，國小六年級學生學習分數概念。學生操弄虛擬教具，輸入分數數值與繪製分數圖，學生以小組合作方式討論虛擬教具呈現之分數圖形，從觀察分數圖中推論出關係（204）。

【示例】Suh（2010）之研究中，國小五年級學生使用虛擬教具學習統計中的集中趨勢（Central Tendency）概念。五年級學生學習統計資料以理解平均數、中位數以及眾數。課程一開始，先收集學生名字之第一個字母，此為初步資料，全班學生使用虛擬教具之箱型圖以記錄他們的資料，且從箱型圖各種觀點來討論集中趨勢。虛擬教具顯示中央趨勢資訊，學生推斷並討論箱型圖之結果，教師隨後提出問題，學生開始思考、批判每筆統計資料之平均數中位數與眾數之關係。接著，學生使用虛擬教具驗證並列出自己的想法。最後，學生看見正確的箱型圖來駁斥先前的驗證（6157）。

(3) 應用

(i) 執行：學生依據程序解決代數之方程式與未知數、統計之問題。

【示例】Figueira-Sampaio, dos Santos & Carrijo（2009）之研究中，國小六年級學生使用虛擬教具解方程式問題。虛擬教具呈現一次多項式問題，而每一組學生使用虛擬教具解決一次多項式問題（3079）。

【示例】Suh & Moyer（2007）之研究中，國小三年級學生使用虛擬教具解決方程式之未知數問題（6106）。

(二) 特定主題內容軟體

特定主題內容軟體通常搭配一般掌上型電腦、筆記型電腦、平板電腦、圖形計算機以及桌上型電腦等硬體使用。最常搭配的是桌上型電腦，而與圖形計算機、電子白板以及投影機搭配使用時，是用以展示操作之螢幕畫面或是操作之媒介。

1. 指導式軟體

當指導式軟體融入學習活動後，學生使用指導式軟體可以提升認知中的記憶與理解層次，記憶部分包含回憶這個認知次項目；理解部分包含詮釋與舉例等兩個認知次項目。

(1) 記憶

(i) 回憶：學生執行並觀賞電腦動畫，加強機率概念。學生根據教師給予的

幾何圖形，繪製出來。

【示例】 Gürbüz & Birgin （2012）之研究中，七年級學生使用 Computer-assisted Teaching CAT) Material 學習機率，學生執行電腦動畫，觀賞動畫內容並回答問題（712）。

【示例】Hauptman（2010）之研究中，十年級學生使用 Virtual Spaces 1.0 software 學習空間概念。學生經教師教導後，使用軟體練習空間相關題目（669）。

【示例】Martin &Velay（2012）之研究中，國小五年級生使用 Computer aided design (CAD) software 學習幾何圖形。學生繪畫出教師給予的 ROCF 幾何圖形（6504）。

(2) 理解

(i) 舉例：學生使用一般性概念或是原則性知識來學習幾何與多項式極限概念，探討平面圖形性質與多項式之極限定義，運用性質或定義創造示例。

【示例】Song & Lee（2002）之研究中，國小六年級生使用 Virtual reality 學習平面概念。教師使用 VR 介紹「一個點不足以構成一個面」之概念，教師用滑鼠點擊此點，會有三架飛機出現且飛越此點，待三架飛機出現後，教師解釋面的概念。教師操作並控制 VR 中的飛機，使其出現在電腦螢幕上，此動態影像引起學生的注意力且增加學生在課堂的參與度。教師使用 VR 物件進行教學，介紹並說明「面」的概念，接著，讓學生在自己的電腦上操作 VR 物件進行學習（2772）。

【示例】 Kidron & Zehavi（2002）之研究中。十年級學生使用 Computer Algebra System 學習極限概念。學生可從視覺化呈現之多項式計算來驗證結果、動態收斂過程視為多項式之極限屬性、計算推理以澄清多項式收斂過程以及構建動畫的命令來說明收斂過程。最後學生藉由改變多項式參數來建立新的動畫，正式定義極限概念（6059）。

【示例】Looi & Lim（2009）之研究中，中學生使用指導式軟體 Alge BAR

學習代數方程式。學生依據已習得方程式之變數定義後，建構方程式模型（2797）。

(ii) 詮釋：學生將動畫轉為分析語言。

【示例】 Kidron & Zehavi（2002）之研究中。十年級學生使用 Computer Algebra System 學習極限概念。教師呈現動畫，學生觀看動畫、了解動畫語法以及將視覺圖像轉化為分析語言（6059）。

2. 反覆練習式軟體

當反覆練習軟體融入學習活動後，學生使用反覆練習式軟體可以提升認知中的記憶層次，包含回憶這個認知次項目。

(1) 記憶

(i) 回憶：學生使用反覆練習軟體進行代數方程式、分數加減法以及小數之概念練習，以強化習得之數學概念。

【示例】Nguyen & Kulm（2005）之研究中，七年級學生於教師教學後，使用反覆練習軟體進行分數概念練習活動，題型為選擇題，學生選取答案，並從反覆練習軟體給予的回饋得知答案是否正確，若不正確則會給予提示，以修正答案，且學生可多次練習，強化分數運算之概念（983）。

【示例】Baki & Güveli（2008）之研究中，九年級學生使用 Web-based mathematics teaching material (WBMT) 練習代數。學生於教師講授課程後，使用 WBMT 進行方程式概念與定義之練習（671）。

3. 問題解決軟體

當問題解決軟體融入學習活動後，學生可以提升認知中的理解、應用以及評鑑層次。而理解部分包含舉例這個認知次項目；應用部分包含執行這個認知次項目；評鑑部分包含檢查這個認知次項目。

(1) 理解

(i) 舉例：學生使用一般性概念或是原則性知識來建構數值表徵、線性圖形以及極限，探討多項式之極限定義，運用性質或定義創造示例。

【示例】Chang, Wu, Weng & Sung（2012）之研究中，國小五年級學生使用 Problem-Posing System 學習創造異分母分數之加法與減法題目，並將問題之內容與答案輸入至提問系統中（734）。

(2) 應用

(i) 執行：學生於教師講授後，根據給予的題目說明，練習解決數值運算、代數以及資料分析等相關問題。

【示例】Harskamp & Suhre（2007）之研究中，學生於教師教學完後，使用 Computer Program 運用習得的知識練習解決題目，在解題過程中，軟體會給予提示（701）。

【示例】Chang, Sung & Lin（2006）之研究中，國小五年級學生使用 MathCA 練習解真分數加減法、分數乘法、三角形面積以及梯形面積等相關問題，在解題過程中，軟體會給予提示（733）。

【示例】Tsuei（2012）之研究中，國小三年級學生以角色輪流扮演方式進行學習活動，兩人一組，一位當教學者，另一位當學習者。教學者使用指導式軟體來示範如何使用數學符號與物件進行數值運算，並說明解題步驟或流程，接著，學習者解決相關問題（6060）。

(3) 評鑑

(i) 檢查：學生試驗自己創造的異分母分數題目，並做適當的修正。

【示例】Chang , Wu, Weng & Sung（2012）之研究中，國小五年級學生使用問題解決軟體 Problem-Posing System 創造異分母分數加法與減法之問題內容，並且試驗自己創造的問題與設定的答案，若有不適當則可修正（734）。

4. 遊戲式軟體

當遊戲式軟體融入學習活動後，學生可以提升認知中的記憶、理解以及應用層次。記憶部分包含識別這個認知次項目；理解部分包含舉例這個認知次項目；應用部分包含執行與實行等二個認知次項目。

(1) 記憶

(i) 識別：學生練習代數相關問題，強化代數概念。

【示例】Bai, Pan, Hirumi & Kebritchi（2012）之研究中，八年級學生於教師教導代數概念後，使用 3-Dmathematics games 進行代數練習，強化代數概念（237）。

【示例】Ke & Grabowski（2007）之研究中，國小六年級學生使用網頁式電腦遊戲學習測量、整數比較、解簡單方程式以及平面座標問題。學生兩人一組使用遊戲進行練習，最後討論解法與修正彼此的迷思概念（灰六）。

(2) 理解

(i) 舉例：學生從遊戲中習得並操弄數學物件，找出並習得向量概念。

【示例】Kynigos & Latsi（2006）之研究中，高中生於遊戲 Juggler' game 之 3D 空間操作遊戲中的球，透過操控球的 X、Y、Z 座標來改變球的方向，以學習向量概念（6066）。

(3) 應用

(i) 執行：學生依一般程序來解決幾何問題。

【示例】Sedig（2008）之研究中，中學生兩人一組，使用 Super Tangrams 解決幾何問題，若學生在解題過程中發生問題時，教師提供學生解題程序性提示（6134）。

(ii) 實行：學生嘗試各種方法來解決代數等式子問題與解決數列排序問題。

【示例】Chen 等人（2012）之研究中，國小四年級學生於遊戲中解決代數問題。學生在運算等式中填入運算符號、將數字填入未知數、使用嘗試錯誤方法解題，最後將解法呈現出來。而學生可從遊戲給予的回饋知道解題是否正確（2843）。

【示例】Lee & Chen（2009）之研究中，九年級學生於線上遊戲解數列相關問題。學生於遊戲中解決數列問題，解題過程中，遊戲會給予學生特

別的提示以幫助學生解題。學生一邊玩遊戲一邊完成學習單，完成學習單後，分享其解法（1503）。

5. 模擬軟體

當模擬軟體融入學習活動後，學生可以提升認知中的理解層次，包含推論這個認知次項目。

(1) 理解

(i) 推論：學生觀察線性圖形，推論線性圖相關特性。模擬機率現象，例如隨機事件中投擲硬幣、袋中選石頭以及湖中捕魚，依據統計資料進行推測並論述。

【示例】Stohl & Tarr（2002）之研究中，六年級學生使用 Probability Explorer Software 學習機率相關概念。學生使用模擬軟體模擬機率現象，包含投擲硬幣、袋中選石頭以及湖中捕魚等事件，從收集、展示以及分析資料進行適當的推論與可信服的論據（灰八）。

由上述分析結果可知，教學軟體於認知層次上的提升包含記憶、理解、應用、分析以及評鑑，其中又以理解層次中的舉例為主，其次為記憶中的回憶與理解中的推論，而評鑑與分析這兩項認知層次最少。

第四節　資訊科技融入數學科教學之成效

本節呈現資料表之「研究結果」欄位彙整結果，並進一步說明資訊科技融入中小學數學科教學之成效。以下分為學習成效、學習動機、學習態度以及其他等四方面詳細說明。

一、學習成效

由資料分析結果可知資訊科技融入數學科教學確能提升學生數學成就，例如學生的數學概念學習、推理與證明能力、解題能力與速度、以及多重表徵間之轉換能力等等。

【示例】Reimer & Moyer（2005）之研究中，國小三年級學生使用虛擬教具學習分數概念後，顯著改善學生分數概念性與程序性知識（6211）。

【示例】Guven（2012）之研究中，中學生使用動態幾何軟體 Cabri 學習幾何圖形之轉換後，從測驗成績可知學生對幾何圖形轉換的理解能力被提升，且對學生的學習具有正向影響（1358）。

【示例】Kramarski & Gutman（2006）之研究中，九年級學生使用 Excel 練習解線性方程式題目後，有助於學生於程序性問題解題，並提升學生之解題能力（688）。

【示例】Hwang, Chen, Dung & Yang（2007）之研究中，國小六年級學生使用電子白板解數值運算與幾何問題後，使學生易於使用數學公式解題，且思辨能力較佳，學生與同儕之間有較好的互動，且教師較能引導其產生更多樣的想法與解法，有助於學生解題與批判性思考（6506）。

【示例】Forster（2007）之研究中，，圖形計算機有助於十二年級學生發展箱形之推論且圖形計算機將數學概念視覺化，有助於學生學習（1873）。

【示例】Chang, Sung & Lin（2006）之研究中，國小五年級學生使用 MathCAL 練習解真分數加減法、分數乘法、三角形面積以及梯形面積等相關問題後，由研究可得知其可有效改善學生解題能力。（733）。

二、學習動機

由資料分析結果可知資訊科技融入數學科教學提升或維持學生學習數學的動機。

【示例】Bai, Pan, Hirumi & Kebritchi（2012）之研究中，3-D mathematics games 提供學生於遊戲情境中學習，提升學生之代數知識的獲得與維持其學習動機，而有助於學生之代數學習（237）。

【示例】Baki & Güveli（2008）之研究中，九年級學生對於使用 Web-based mathematics teaching material (WBMT)學習會越來越熟悉解題過程與步驟，而提升學習自信心並且表現出高度學習動機（671）。

【示例】Erbas & Yenmez（2011）之研究中，動態幾何軟體 Geometer’s Sketchpad 促進國小六年級學生促進學生學習動機，學生主動參與學習活動，發表自己的意見並與組員討論以學習幾何圖形之特性（708）。

但有些研究結果並未發現學生學習數學之動機得到明顯提升，例如文獻編號 6134。Sedig（2008）之研究中，中學生兩人一組，使用 Super Tangrams 解決幾何問題，雖有顯著改善學生幾何問題之解決，但是學生學習動機無正面之影響（6134）。

三、學習態度

由資料分析結果可知資訊科技融入數學科教學可增進學生學習數學的態度，例如自信心、責任心以及對科技工具輔助學習抱持正向的心態等等。

【示例】Reimer & Moyer（2005）之研究中，國小三年級學生對於使用虛擬教具學習分數概念是持正向的態度。學生喜歡虛擬教具的立即回饋，並且認為虛擬教具相較於紙筆比較容易且快速使用，使學生有正向的學習經驗（6211）。

【示例】Figueira-Sampaio, dos Santos & Carrijo（2009）之研究中，國小六年級學生操弄虛擬教具學習一次多項方程式之後，提升學生的解題信心、促進同儕間之互動與責任心。懂得提出問題並聆聽同儕意見、關心彼此的學習狀況、高成就者引導能力較低同儕解題（3079）。

【示例】Ke & Grabowski（2007）之研究中，國小六年級學生使用網頁式電腦遊

戲學習測量、整數比較、解簡單方程式以及平面座標問題後，提升學生學習數學之正向態度，進而有好的學習成效（灰六）。

【示例】Nguyen, Hsieh & Allen（2006）之研究中，學生使用 Web-based Assessment and Practice（WP）練習分數概念後，提升學生學習數學自信心（983）。

四、其他

從納入分析之文獻中，可知資訊科技融入中小學數學科教學除了提升或增進學生的學習成就、學習動機及學習態度之外，有少數幾篇研究專注於探討學生使用科技工具所發展之學習或解題策略。

【示例】Wei & Ismail（2010）之研究中，發現國小五年級學生使用動態數學軟體學習計算與比較不規則幾何圖形面積時，多半使用經驗策略，包含視覺驗證、適應性驗證；測量策略，包含公式驗證、概述與自動量測驗證；特殊策略，包含複製與貼上驗證、擦去與重繪驗證、轉換驗證、屬性驗證等策略（3522）。

【示例】Kordaki（2003）之研究中，學生使用指導式軟體 The ‘Conservation of Area and its Measurement’ (C.AR.ME.) Microworld 建構幾何圖形時候使用不同策略，其使用策略種類有自動轉換、模擬、面積量測運算以及拖拉工具，學習幾何圖形面積轉換與比較等，有助於學生學習（1252）。

【示例】Chen, Looi, Lin, Shao & Chan（2012）之研究中，學生於遊戲軟體中，發現學生有五種運算方法，包含個人運算、比較、傳達、輔助運算以及重頭至尾運算；不同的計算方式，包含自由計算、重頭開始計算、從尾開始計等，有助於合作式學習與發展數值運算之概念（2843）。

【示例】Kordaki & Balomenou（2006）之研究中，中學生使用動態幾何軟體 Cabri 學習幾何問題中等面積三角形之概念。發現學生使用的策略種類有，用眼睛、保留長度或原來三角形之長度與角度、使用軟體幾何轉換之命令、分割多邊形、產生全等三角形、將拖拉模式與自動面積測量結合使用、保留基本長度與頂點距離、使用中點將三幾行平分、使用單位面積測量面積、使用面積公式，藉由分割多邊形以將原本的三角形以轉換為另一個全等三角形。而小組使用策略：使用等距建

構全等三角形。跨策略種類：使用等距與拖拉模式建構三角形。有助於學生學習幾何概念（1911）。

【示例】Hwang, Chen & Hsu（2006）之研究中，國小六年級學生使用電子白板學習分數除法。學生使用多種策略解題，像是化為同分母做除法、將除數顛倒後再和被除數相乘，學生使用將除數顛倒後再和被除數相乘之策略等，有助於學生學習解題（660）。

第五章　結論與建議

本章一共分為三節，第一節為結論，針對本研究結果歸納資訊科技融入中小學數學科教學之研究結果；第二節為教學應用建議，針對本研究之研究結果提出資訊科技融入中小學數學科教學的具體建議；第三節為未來研究相關建議，針對本研究所發現的問題與不足之處，提出未來研究之建議。

第一節 結論

本研究運用系統性文獻分析法，收集自 2000 年至 2012 年之資訊科技工具融入中小學數學科文獻，並進行類別之統計與質性方式彙整、編碼及分析這些文獻的學習活動、使用之科技工具以及科技工具之特性，進而了解資訊科技融入中小學數學科教學之概況。根據第四章的研究結果與發現，可獲致以下結論：

一、資訊科技融入中小學數學科之現況

針對教育階段、教學主題以及融入教學工具此三部分進行類別之統計資料彙整，獲得結果如下：

1. 教育階段

   納入分析研究報告之文獻中，其中以國小篇數為最多，其次是國中，而高中則篇數為最少。由此可知，資訊科技融入中小學數學科教學於國小階段最為普遍。

2. 融入之數學科教學主題

   數學科可分為五大教學主題：數與運算、幾何、幾何、測量以及資料分析與機率，由納入分析研究報告之文獻，可知資訊科技融入中小學數學科之教學單元以「數與運算」與「幾何」為主，這個研究結論與 Moyer 等人（2008）的研究結果相符，因為該二單元涉及抽象思考，資訊科技工具使學生易於習

得這些難以理解的數學概念。

3. 融入教學之科技工具種類

本研究將資訊科技工具分為硬體與軟體兩大類。硬體包含桌上型電腦、圖形計算機、電子白板、筆記型電腦、平板電腦、投影機以及掌上型電腦等。從納入分析之文獻中可知，融入中小學數學科教學時，硬體工具以桌上型電腦為主，其次為圖形計算機與電子白板；而軟體可分為工具軟體與教學軟體，融入中小學數學科教學時，工具軟體以辦公用套裝軟體、電子白板之內建軟體、以及圖形計算機之內建軟體為主；教學軟體則是以虛擬教具、動態幾何軟體以及指導式軟體最多。

二、資訊科技工具有助於學習之特性

從納入分析的文獻中彙整可知，科技工具之特性主要是「互動性」與「視覺化」兩種：

1. 互動性

互動性包含「人際互動」及「人機互動」兩種。人際互動為同儕互動，其使學生之間有更多的分享、溝通與討論、協商、反思、針對彼此所提出之想法或意見給予回饋與評論，進而提升學習成效，這些結果都是由於科技工具融入學習活動所造成。而學生與教材互動則依教材之性質，包含與學習情境或學習物件互動。科技工具提供各種真實或有趣的學習環境，使學生的學習變得更加生動有趣，不再枯燥乏味，因而提升學習的認同和主動性。此外，資訊科技工具所能提供之豐富的學習教材與練習範例，亦使學生可以不斷地練習以強化與澄清數學概念。學生亦能透過自我學習步調之調控，不會錯過應學習之內容。科技工具對學生學習行為給予一些限制，使其於能更加專注於學習活動中而不易分心。

2. 視覺化

科技工具之視覺化特性包含回饋與提示、數學表徵之呈現以及操弄。這些功

能可協助並促進學生覺察與驗證其推理之合理性與正確性，從中以調整其思維，而能有效促進學生進行有意義性之思考，也讓學生有更多反省、討論和溝通的行為。而科技工具呈現多重表徵之動態連結，使學生能將抽象概念具體化，易於理解困難的概念。因此，科技工具之視覺化特性確實能帶給學生不一樣的學習經驗且能提升其學習成效。

三、資訊科技融入教學對提升學生認知過程之影響

研究者將納入分析之文獻所報導之「學習活動」依據布魯姆認知領域教育目標分類修正版進行編碼，從分析結果發現資訊科技融入中小學數學科教學能提升學生之認知過程發展之記憶、理解、應用、分析以及評鑑等層次，其中以理解層次為主，其次為應用與記憶；分析層次最少，而創造層次則完全沒有出現在納入分析之文獻中。若進一步探討，依據軟體種類又可分為工具軟體與教學軟體。

工具軟體於認知層次上的提升包含記憶、理解、應用以及評鑑，其中又以理解層次中的舉例為主,其次為應用中的執行與理解中的詮釋;而記憶與評鑑最少，分析與創造層次則完全沒有。

教學軟體於認知層次上的提升包含記憶、理解、應用、分析以及評鑑，其中又以理解層次中的舉例為主，其次為記憶中的回憶與理解中的推論；而評鑑與分析最少，創造層次則完全沒有。

從上述研究之分析結果可知，由於資訊科技融入中小學數學科教學後，打破以往傳統之教學方式與學習方式，確實有助於學生認知層次之發展。但是，科技工具目前尚無法幫助學生的認知層次提升到創造部分。

第二節 教學應用之建議

根據本研究之資料分析結果，提出下列建議以提供未來研究與數學教學之參考。

一、教學上之建議

數學教師應事先了解資訊科技融入教學後，能讓學生之認知發展達到哪一個層次。由於每一種科技工具之融入方式不同，使得學生於學習活動使用科技工具之方式也會有所不同，故學生認知層次之發展也會受到影響。數學教師想讓學生之認知發展達到哪一個層次時，應先了解各種科技工具融入學生之學習活動後，能幫助學生發展至預設的認知層級，使教學能事半功倍。

二、教材上之建議

數學教師在進行資訊科技融入教學之前，無論教師擬自行開發教材，或考慮該使用哪一種科技工具時，均應先了解該工具有哪些特性，並考量這些特性能否為學生帶來不一樣的學習經驗，使之對數學之學習更有興趣與動機，進而對學習數學更有信心。因此，數學教師於資訊科技融入教學前，應慎選適當的科技工具以融入其教學。

第三節　未來研究之建議

一、延續並擴大收集文獻之年份與範圍

就研究對象之時間來說，本研究是以 2000 年 1 月 1 日至 2012 年 12 月 31 日所發表之資訊科技融入數學科教學相關文獻進行分析，但資訊科技融入數學科教學之相關研究會不斷地累積，所以未來研究可以將時間延長，以更加了解資訊科技融入數學科教學之概況，也許會有令人意想不到的發現。

就研究對象之教育階段來說，本研究是以中、小學為主，然而，許多大專院校之數學相關課程也實施資訊科技融入教學，故未來研究可以將教育階段擴大至大專院校，進而更加了解資訊科技融入數學科教學之整體情況。

二、資訊科技融入各領域之教學

由於資訊科技融入教學於各個學習領域是一個整體趨勢，因此，除了數學科之外，其他科目亦應進行系統性文獻分析，檢視科技工具在各個學科之融入情形，使各科教師能對資訊科技融入教學更加了解，並且能適時且適當地將科技工具融入其教學中，也能更加了解學生之學習情況，並於教學上做適當地調整，進而提升教學效益。

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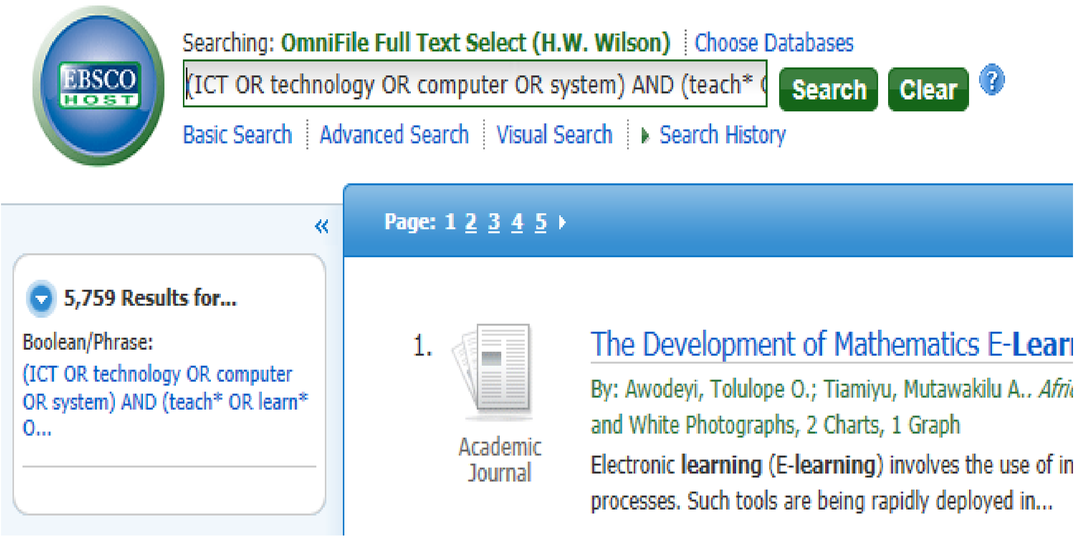
附錄

附錄一 電子資料庫搜尋過程圖

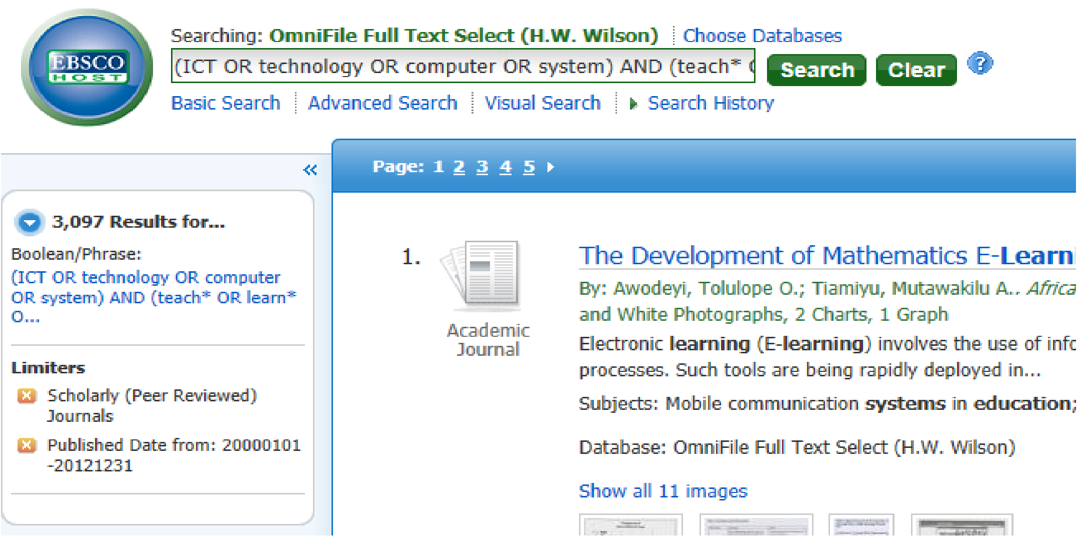
一、EBSCOhost

1. 輸入 Keyword：

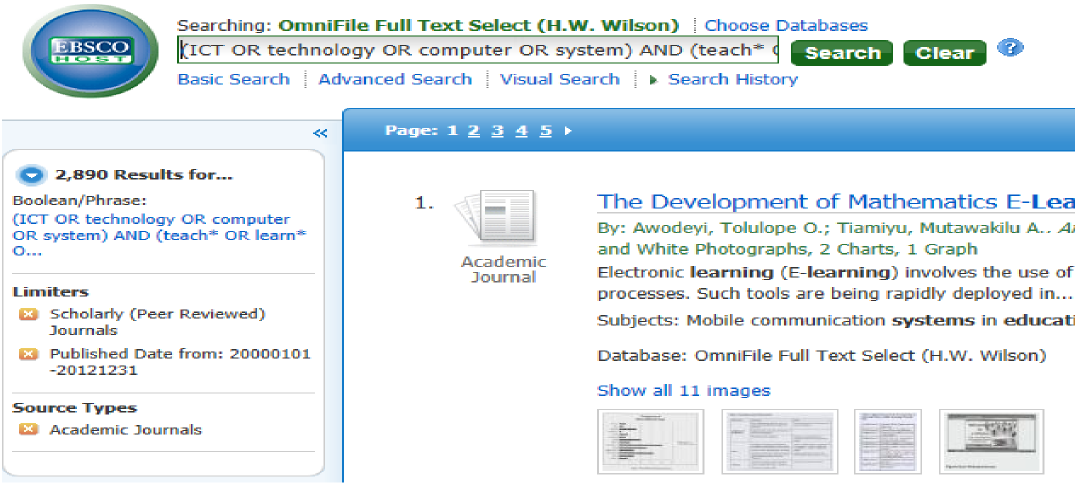
(ICT OR technology OR computer OR system) AND (teach* OR learn* OR educat* OR instruct* OR pedagogi*) AND math*



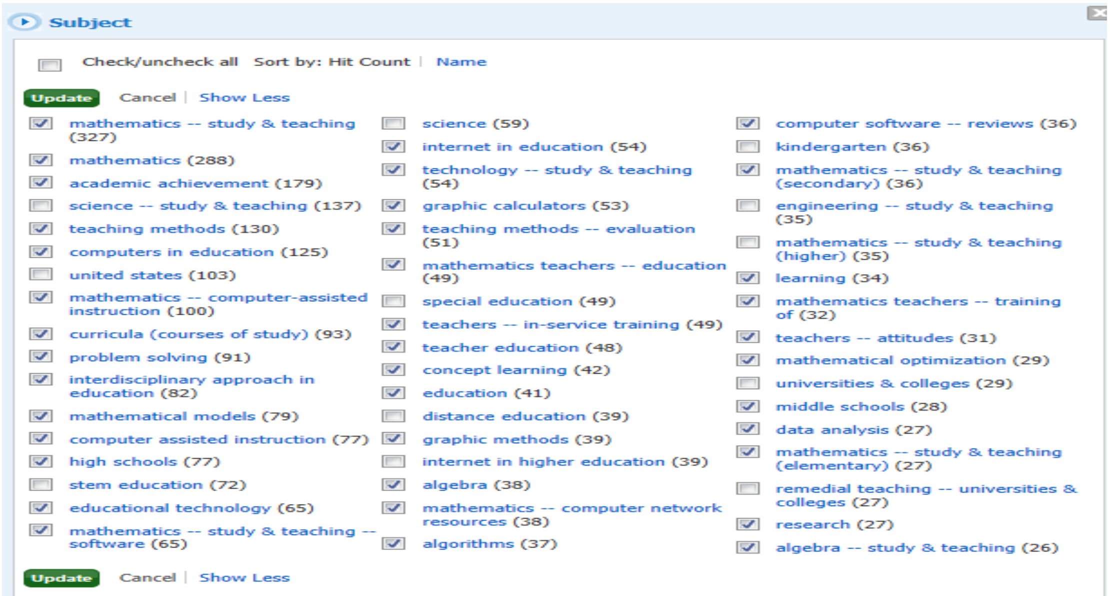
2. 加入條件： Scholarly (Peer Reviewed) Journals 與 Published Date from:2000-2012

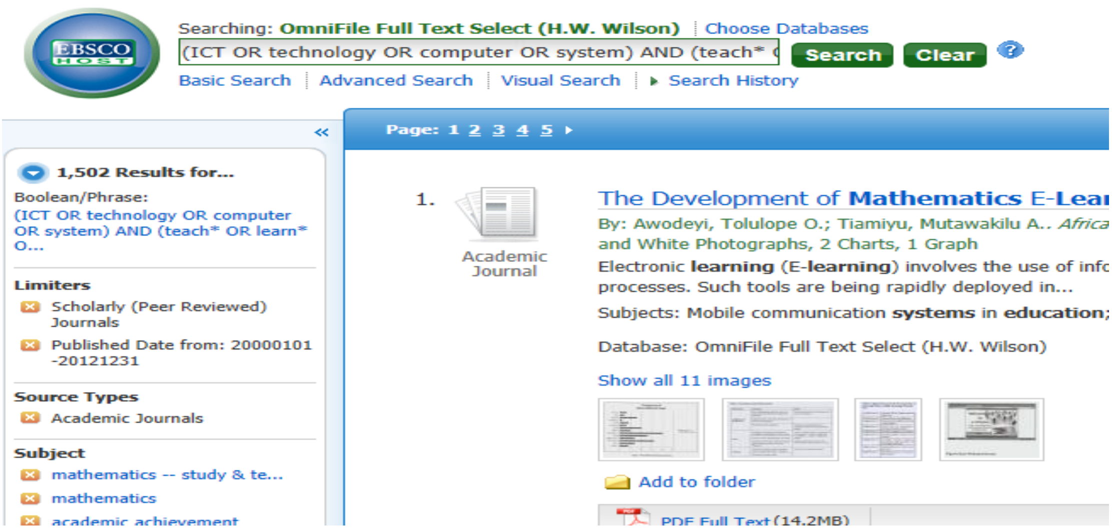


3. 加入條件：Source Types



4. 加入條件：Subject

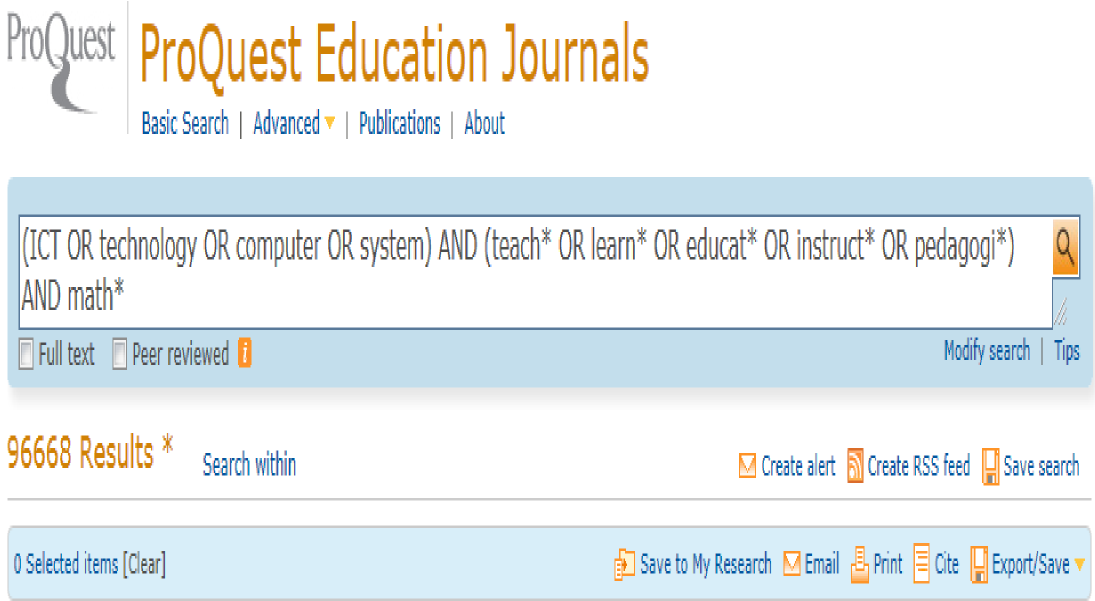




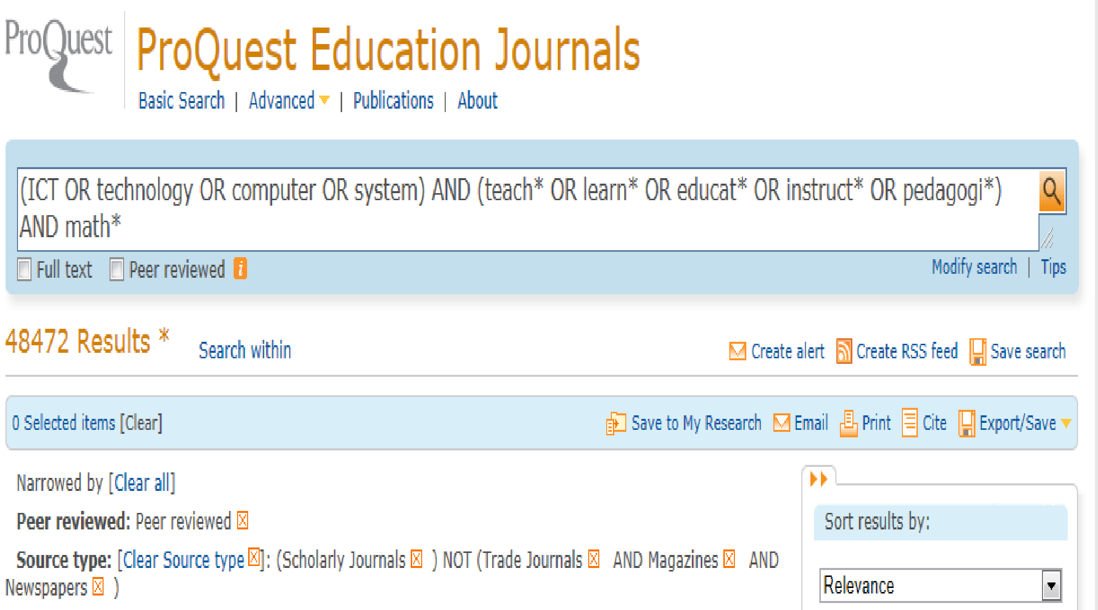
二、Education Journals (Proquest)

1. 輸入 Keyword：

(ICT OR technology OR computer OR system) AND (teach* OR learn* OR educat* OR instruct* OR pedagogi*) AND math*

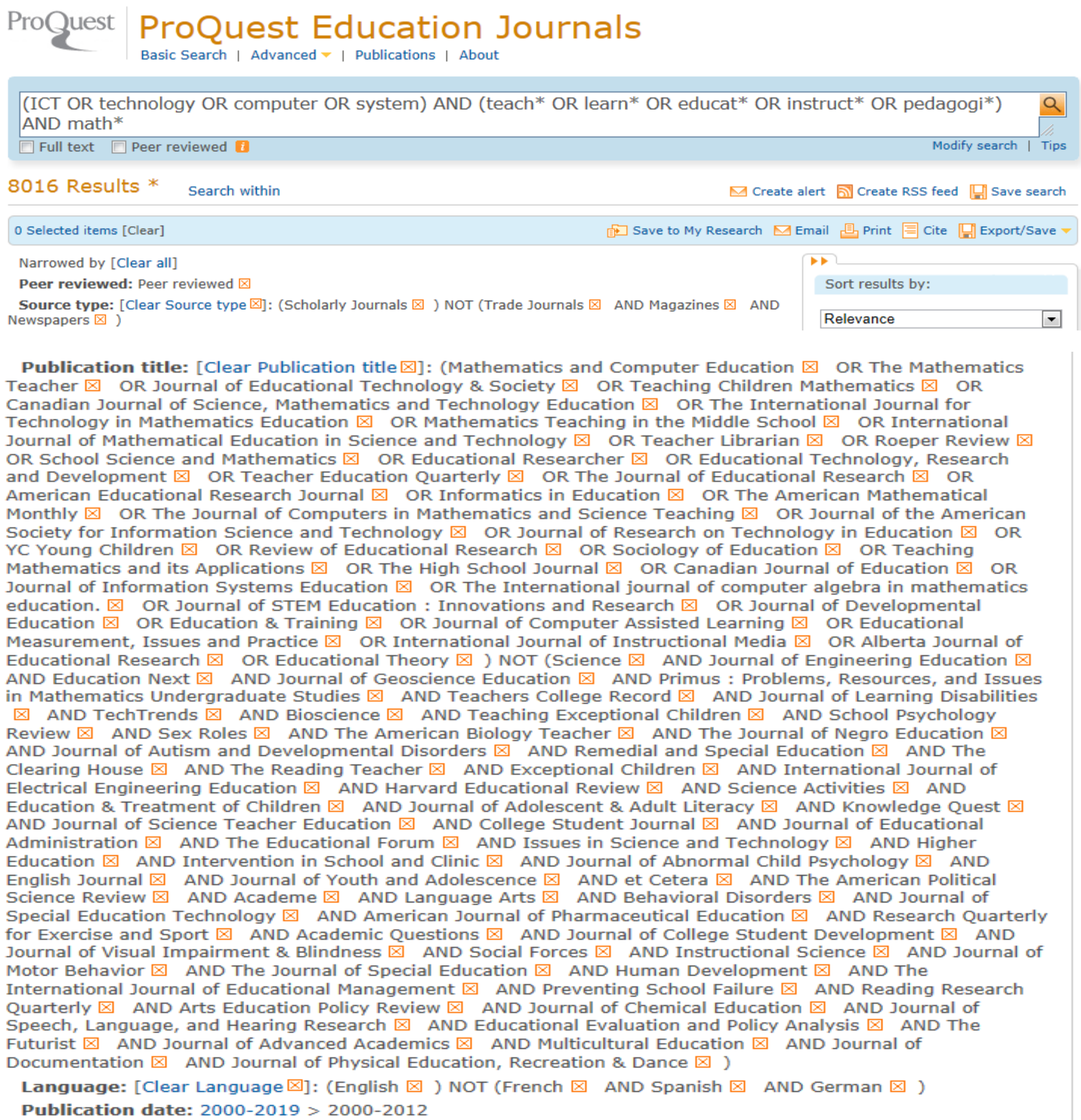


2. 加入條件：Peer reviewed 與 Source type



3. 加入條件：Language 與 Publication date (2000-2012)

4. 加入條件：Publication title



5. 加入條件：Document type

ProQuest

ProQuest Education Journals

Basic Search | Advanced | Publications | About

(ICT OR technology OR computer OR system) AND (teach* OR learn* OR educat* OR instruct* OR pedagogi*) AND math*

Full text Peer reviewed Modify search | Tips

6006 Results * Search within Create alert Create RSS feed Save search

400 Selected items [Clear] Save to My Research Email Print Cite Export/Save

Narrowed by [Clear all]

Peer reviewed: Peer reviewed ☒

Source type: [Clear Source type ☒]: (Scholarly Journals ☒) NOT (Trade Journals ☒ AND Magazines ☒ AND Newspapers ☒)

Sort results by:

Relevance

Publication title: [Clear Publication title ☒]: (Mathematics and Computer Education ☒ OR The Mathematics Teacher ☒ OR Journal of Educational Technology & Society ☒ OR Teaching Children Mathematics ☒ OR Canadian Journal of Science, Mathematics and Technology Education ☒ OR The International Journal for Technology in Mathematics Education ☒ OR Mathematics Teaching in the Middle School ☒ OR International Journal of Mathematical Education in Science and Technology ☒ OR Teacher Librarian ☒ OR Roeper Review ☒ OR School Science and Mathematics ☒ OR Educational Researcher ☒ OR Educational Technology, Research and Development ☒ OR Teacher Education Quarterly ☒ OR The Journal of Educational Research ☒ OR American Educational Research Journal ☒ OR Informatics in Education ☒ OR The American Mathematical Monthly ☒ OR The Journal of Computers in Mathematics and Science Teaching ☒ OR Journal of the American Society for Information Science and Technology ☒ OR Journal of Research on Technology in Education ☒ OR YC Young Children ☒ OR Review of Educational Research ☒ OR Sociology of Education ☒ OR Teaching Mathematics and its Applications ☒ OR The High School Journal ☒ OR Canadian Journal of Education ☒ OR Journal of Information Systems Education ☒ OR The International journal of computer algebra in mathematics education. ☒ OR Journal of STEM Education : Innovations and Research ☒ OR Journal of Developmental Education ☒ OR Education & Training ☒ OR Journal of Computer Assisted Learning ☒ OR Educational Measurement, Issues and Practice ☒ OR International Journal of Instructional Media ☒ OR Alberta Journal of Educational Research ☒ OR Educational Theory ☒) NOT (Science ☒ AND Journal of Engineering Education ☒ AND Education Next ☒ AND Journal of Geoscience Education ☒ AND Primus : Problems, Resources, and Issues in Mathematics Undergraduate Studies ☒ AND Teachers College Record ☒ AND Journal of Learning Disabilities ☒ AND TechTrends ☒ AND Bioscience ☒ AND Teaching Exceptional Children ☒ AND School Psychology Review ☒ AND Sex Roles ☒ AND The American Biology Teacher ☒ AND The Journal of Negro Education ☒ AND Journal of Autism and Developmental Disorders ☒ AND Remedial and Special Education ☒ AND The Clearing House ☒ AND The Reading Teacher ☒ AND Exceptional Children ☒ AND International Journal of Electrical Engineering Education ☒ AND Harvard Educational Review ☒ AND Science Activities ☒ AND Education & Treatment of Children ☒ AND Journal of Adolescent & Adult Literacy ☒ AND Knowledge Quest ☒ AND Journal of Science Teacher Education ☒ AND College Student Journal ☒ AND Journal of Educational Administration ☒ AND The Educational Forum ☒ AND Issues in Science and Technology ☒ AND Higher Education ☒ AND Intervention in School and Clinic ☒ AND Journal of Abnormal Child Psychology ☒ AND English Journal ☒ AND Journal of Youth and Adolescence ☒ AND et Cetera ☒ AND The American Political Science Review ☒ AND Academe ☒ AND Language Arts ☒ AND Behavioral Disorders ☒ AND Journal of Special Education Technology ☒ AND American Journal of Pharmaceutical Education ☒ AND Research Quarterly for Exercise and Sport ☒ AND Academic Questions ☒ AND Journal of College Student Development ☒ AND Journal of Visual Impairment & Blindness ☒ AND Social Forces ☒ AND Instructional Science ☒ AND Journal of Motor Behavior ☒ AND The Journal of Special Education ☒ AND Human Development ☒ AND The International Journal of Educational Management ☒ AND Preventing School Failure ☒ AND Reading Research Quarterly ☒ AND Arts Education Policy Review ☒ AND Journal of Chemical Education ☒ AND Journal of Speech, Language, and Hearing Research ☒ AND Educational Evaluation and Policy Analysis ☒ AND The Futurist ☒ AND Journal of Advanced Academics ☒ AND Multicultural Education ☒ AND Journal of Documentation ☒ AND Journal of Physical Education, Recreation & Dance ☒)

Document type: [Clear Document type ☒]: (Article ☒) NOT (Feature ☒ AND Review ☒ AND General Information ☒ AND Commentary ☒ AND Front Matter ☒ AND Table of Contents ☒ AND Credit/Acknowledgement ☒ AND News ☒ AND Editorial ☒ AND Interview ☒ AND Case Study ☒ AND Report ☒ AND Literature Review ☒ AND Bibliography ☒ AND Directory ☒ AND Front Page/Cover Story ☒ AND Speech/Lecture ☒ AND Conference Paper ☒ AND Instructional Material/Guideline ☒ AND Back Matter ☒ AND Correspondence ☒ AND Obituary ☒ AND Correction/Retraction ☒ AND Recipe ☒ AND Statistics/Data Report ☒ AND Website/Webcast ☒)

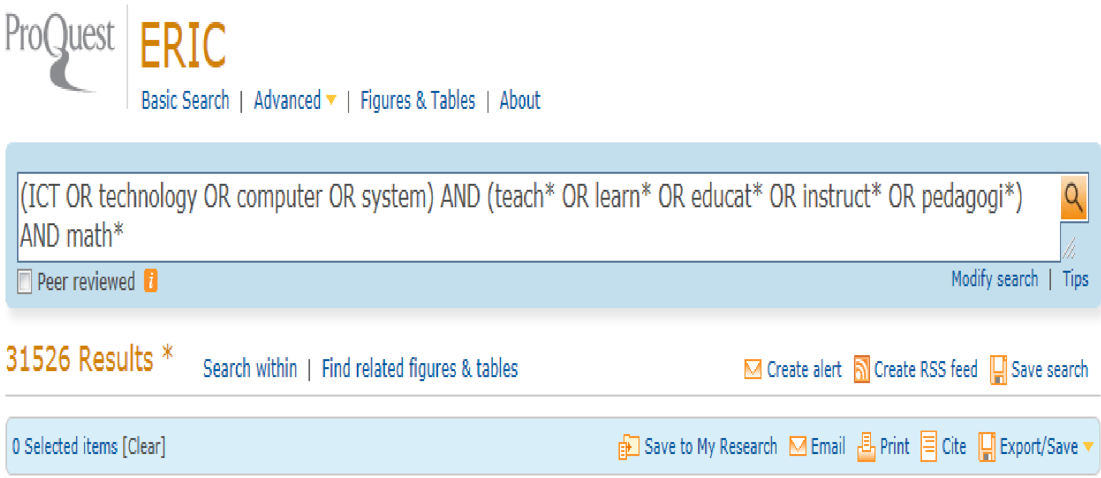
Language: [Clear Language ☒]: (English ☒) NOT (French ☒ AND Spanish ☒ AND German ☒)

Publication date: 2000-2019 > 2000-2012

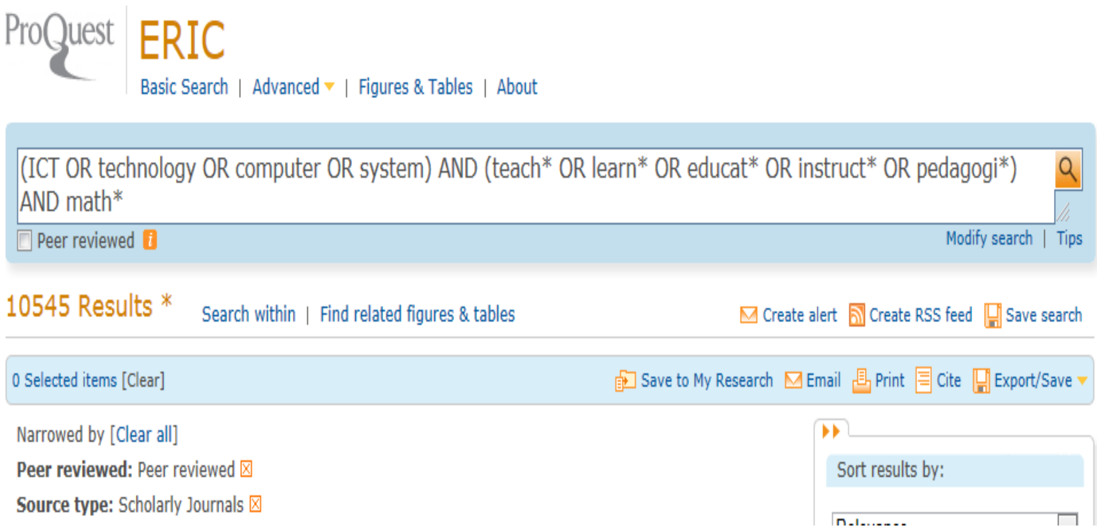
三、Eric (ProQuest)

1. 輸入 Keyword：

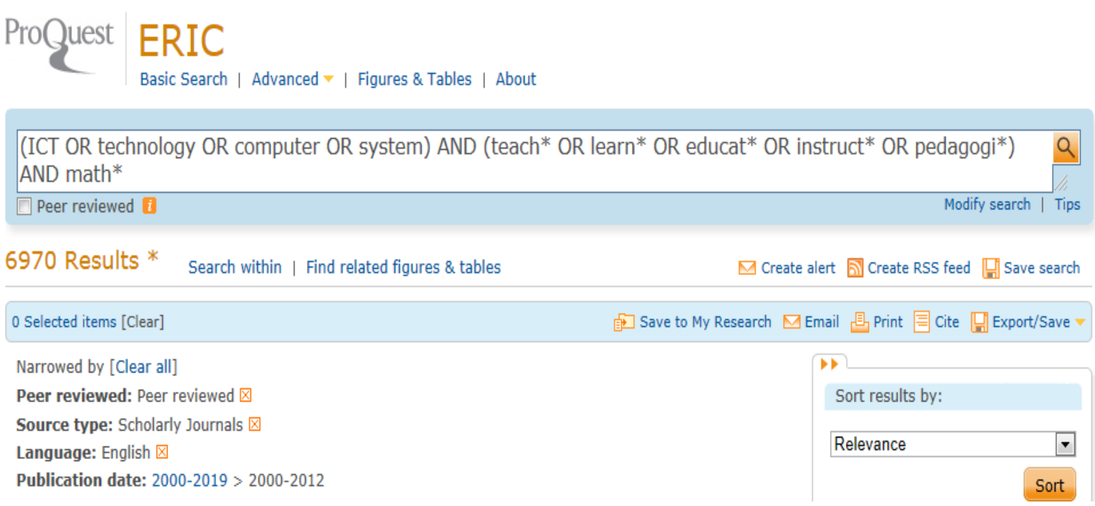
(ICT OR technology OR computer OR system) AND (teach* OR learn* OR educat* OR instruct* OR pedagogi*) AND math*



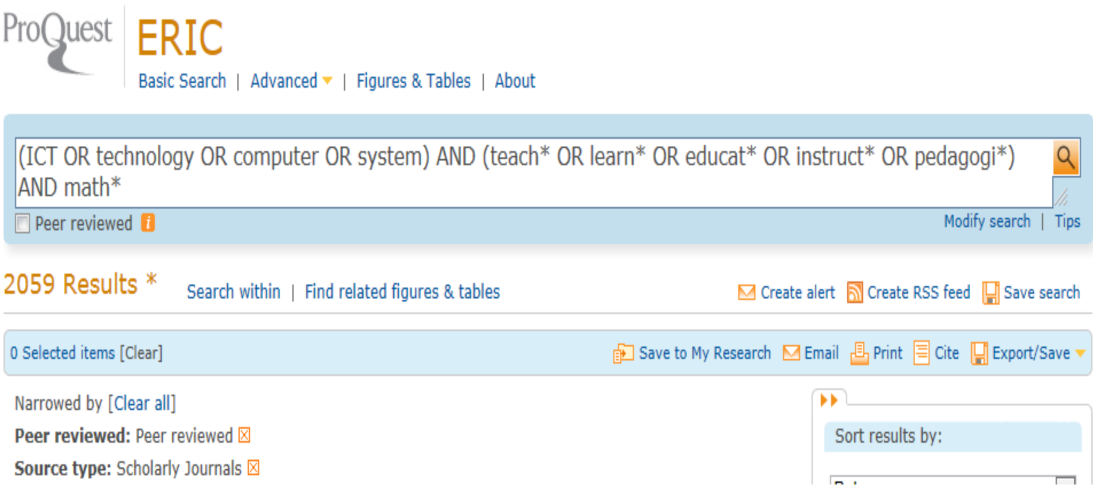
2. 加入條件：Peer reviewed 與 Source type



3. 加入條件：Language 與 Publication date (2000-2012)



4. 加入條件：Subject



Subject: [Clear Subject ☒]: (mathematics instruction ☒ OR teaching methods ☒ OR mathematics education ☒ OR educational technology ☒ OR computer uses in education ☒ OR problem solving ☒ OR mathematical concepts ☒ OR computer software ☒ OR equations (mathematics) ☒ OR mathematics ☒ OR algebra ☒ OR computer assisted instruction ☒ OR student attitudes ☒ OR mathematics teachers ☒ OR mathematics achievement ☒ OR academic achievement ☒ OR calculus ☒ OR computation ☒ OR secondary school mathematics ☒ OR comparative analysis ☒ OR mathematical logic ☒ OR instructional effectiveness ☒ OR geometry ☒ OR mathematics skills ☒ OR geometric concepts ☒ OR technology integration ☒ OR mathematical formulas ☒ OR educational change ☒ OR technology education ☒ OR internet ☒ OR case studies ☒ OR teacher attitudes ☒ OR elementary secondary education ☒ OR mathematical models ☒ OR high school students ☒ OR thinking skills ☒ OR preservice teachers ☒ OR secondary education ☒ OR elementary school mathematics ☒ OR instructional design ☒ OR information technology ☒ OR evaluation methods ☒ OR professional development ☒ OR video technology ☒ OR preservice teacher education ☒ OR cognitive processes ☒ OR elementary school students ☒ OR statistics ☒ OR statistical analysis ☒ OR high schools ☒ OR probability ☒ OR middle school students ☒ OR electronic learning ☒ OR student evaluation ☒ OR technology uses in education ☒ OR computer simulation ☒ OR educational strategies ☒ OR mathematics curriculum ☒ OR numbers ☒ OR student motivation ☒ OR mathematics tests ☒ OR graphs ☒ OR intervention ☒ OR cooperative learning ☒ OR curriculum development ☒ OR mathematics activities ☒ OR educational environment ☒ OR web based instruction ☒ OR computer mediated communication ☒ OR secondary school teachers ☒ OR computer assisted testing ☒ OR graphing calculators ☒) NOT (foreign countries ☒ AND college mathematics ☒ AND science education ☒ AND science instruction ☒ AND higher education ☒ AND models ☒ AND engineering education ☒ AND college students ☒ AND validity ☒ AND physics ☒ AND program effectiveness ☒ AND interviews ☒ AND stem education ☒ AND undergraduate students ☒ AND engineering ☒ AND gender differences ☒ AND scientific concepts ☒ AND questionnaires ☒ AND correlation ☒ AND college science ☒ AND pretests posttests ☒ AND undergraduate study ☒ AND scores ☒ AND feedback (response) ☒ AND females ☒ AND science teachers ☒ AND predictor variables ☒ AND chemistry ☒)

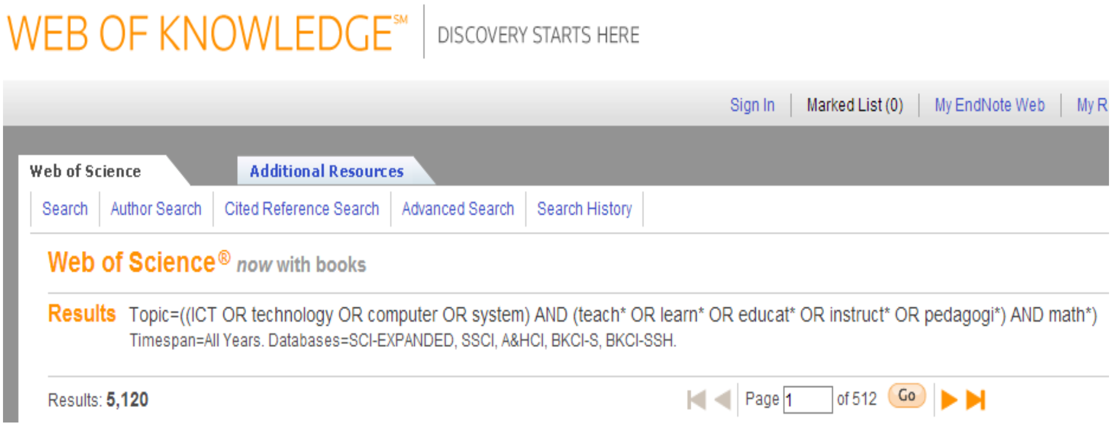
Language: English ☒

Publication date: 2000-2019 > 2000-2012

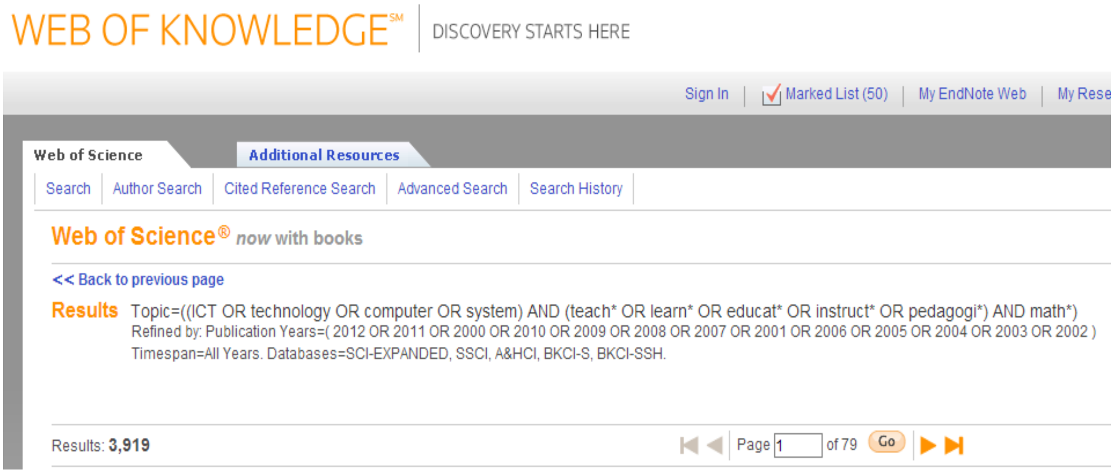
四、ISI Web of knowledge

1. 輸入 Keyword：

(ICT OR technology OR computer OR system) AND (teach* OR learn* OR educat* OR instruct* OR pedagogi*) AND math*



2. 加入條件：Publication Years (2000-2012)

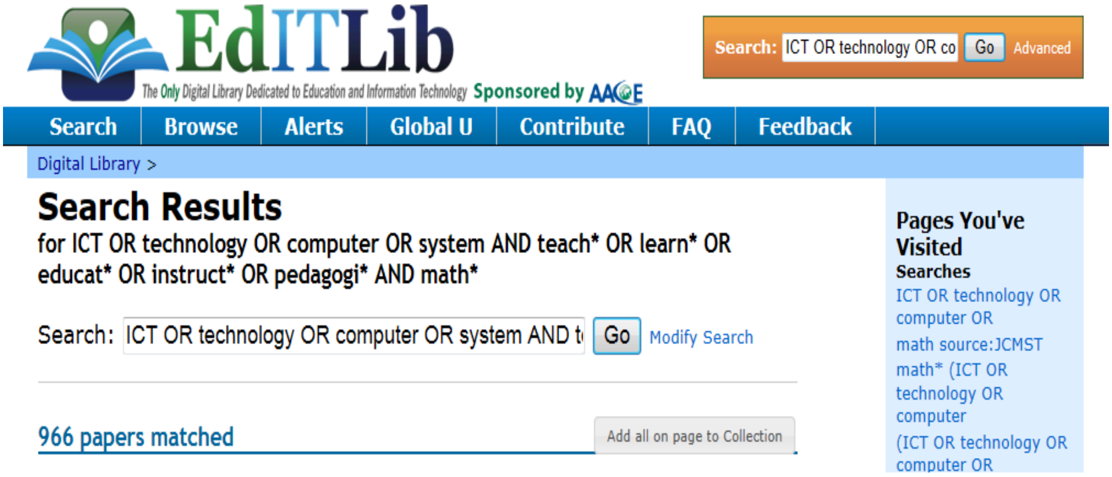


3. 加入條件：Subject Area (Education Educational Research)

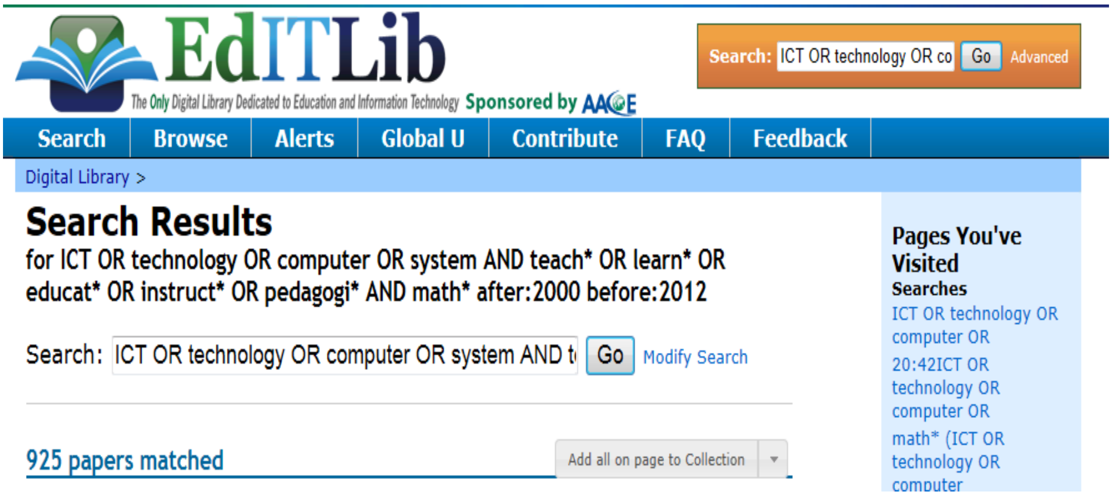
五、EdITLib

1. 輸入 Keyword:

(ICT OR technology OR computer OR system) AND (teach* OR learn* OR educat* OR instruct* OR pedagogi*) AND math*



2. 加入條件：Publication Years (2000-2012)



附件二 資料萃取表格

編號:157

Data Extraction Form	
欄位名稱	內容
文獻來源	Brown, J. (2004). A Difficult Function. Australian Mathematics Teacher, 60(2), 6-11.
研究目的	A case study was undertaken to explore student understanding from the perspective of how graphing calculators are used during a task to demonstrate understanding of functions.
研究問題	1.What mathematical and graphing calculator knowledge would you or your students use given each of the views above in order to facilitate the determination of a global view of the functions under consideration? 2. Would you and your students use the same or different knowledge? 3. How do we explicitly teach this mathematical and graphing calculator knowledge? 4. What learning situations can we provide for our students that allow them to consider applying a range of mathematical and graphing calculator knowledge to ensure they have myriad options so that when a situation occurs where their preferred or usual application of knowledge is ineffective they have other choices available?
研究方法	Case study
教學單元	□數與運算(Number & Operations) ■代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	This mathematical knowledge included the possible shapes of cubic functions, more specific knowledge informed by the algebraic representation of the function including information regarding the shape, the coordinates of the y intercept, the existence of at least one x intercept, and the domain of the function being all real numbers.
教育階段	□國小 □國中 ■高中 two from Year 12 and three from Year 11
融入教學之工具	Graphing calculator
學習活動 (Learning activity)	教學策略:合作式學習(students working cooperatively to produce a sketch of the complete graph of a difficult cubic function)
	Students working cooperatively to produce a sketch of the complete graph of a difficult cubic function. Before reading any further use your graphing calculator to help find a complete graph of the following function. Take note of the mathematical and graphing calculator knowledge used in your nsolution process. All five pairs eventually solved the task. The knowledge and choices of one of the Year 12 pairs enabled them to apply their mathematical and graphing calculator knowledge in a way that ensured that their solution process quickly became routine. None of the other pairs of students consistently applied their mathematical and graphing calculator knowledge in conjunction with sensible choices of actions. One aspect of graphing calculator knowledge that was applied by all pairs was adjusting the WINDOW settings. All pairs undertook this action in their initial search for a global view of the graphical representation of the function, however only when combined with mathematical knowledge and

	additional graphing calculator knowledge did this lead to the solution process becoming routine or potentially routine. One Year 11 pair, for instance, after initially zooming out twice saw the view. From their dialogue and their adjustment of both the y minimum and maximum values, it can be inferred that this pair were unaware of the section of the graph coincident with the y axis. The steepness of the lines did not stop their using their mathematical knowledge to infer that there must be a turning point in the viewing domain under observation, however. As they were unsure of the type of turning point, they sensibly adjusted both end points of their viewing range. These changes resulted in a maximum turning point becoming visible in the viewing window , albeit probably not quite where they expected. In contrast, application of mathematical and graphing calculator knowledge by a second Year 11 pair was apparent from their use of the y intercept to inform their decision to alter the WINDOW settings. By selecting a viewing range that included the y ordinate of the y intercept, this pair could reasonably expect to see a view of the graph intersecting the y axis in the resulting viewing window. The resulting view, however, showed one part of the graph coincident with the y axis, a fact the students may not have realised, as this was most probably their first experience of this situation. However, neither student explicitly commented on the lack of a visible y intercept and this lack of application of mathematical knowledge hindered a potentially routine solution. All pairs undertook actions that demonstrated they had a clear mental image of the function for which they were searching and the possible position of the output of thegraphing calculator relative to this , but at times their actions were not consistent with this, notably when confronted withdifficult views of the function . The actions of some pairs suggested that they temporarily did not have a clear idea which section of the function was currently the focus for the viewing window. However, a view that proved difficult for one pair was not necessarily difficult for another pair.
所收集之 研究資料	The subsequent videotaping of this projection went some way to overcoming this difficulty. The record of the results of students' actions and videotaping of graphing calculator screen outputs supplemented audio recordings, observational notes, and students' scripts allowing new insight into student understandings to be gained.
研究結果	Evidence from this study supports the view that the combined application of mathematical and graphing calculator knowledge is more efficient and effective in the determination of a global view of a difficult function. In addition they all had the ability to adjust the current view presented by the graphing calculator, albeit varied in efficiency and effectiveness, to find an appropriate window for the function.
科技工具之特點	Students mental image of the archetypical function under consideration and the use of the automatic range scaling feature for a given domain.The use of an automatic range scaling feature for a given domain, for instance, Zoom Fit on the TI-83 or Autoscale on the HP38G, can facilitate the determining of a global view of a difficult function.

編號:168

Data Extraction Form	
欄位名稱	內容
文獻來源	Ghosh, J.(2004). Exploring concepts in probability using graphics calculators. Australian Mathematics Teacher, 60(3), 25-31.
研究目的	The primary objective of the project was for students to explore some basic concepts in probability using graphics calculators in the regular traditional classroom environment. In particular the aims were to: ・ introduce the concept of randomness; ・ emphasise the difference between empirical and theoretical probabilities of an event; ・ introduce the concept of simulation and highlight its importance; ・ simulate experiments such as the throwing of coin(s) or dice and the birthday problem using a graphics calculator.
研究問題	
研究方法	There are 12 sections of year 10 with class sizes ranging between 45 and 50. The 45 students who participated inthis project were selected from across these 12 sections. Most of these students were members of a mathematics lab and were familiar with the Casio CFX 9850GB PLUS graphics calculator. It was decided by the mathematics staff that the selected students would participate in the project only after they had undergone the regular classroom lessons with the rest of their classmates so that the regular schedule of teaching was not disturbed.
教學單元	□數與運算(Number & Operations) □代數(Algebra) □幾何(Geometry) □測量(Measurement) ■資料分析與機率(Data Analysis & Probability)
教學主題	Probability
教育階段	□國小 □國中 ■高中 Forty-five students in Year 10.
融入教學之工具	Casio CFX 9850 GB PLUS graphics calculator
學習活動 (Learning activity)	教學策略:
	＊Graphics calculator lessons During the technology lessons a worksheet was given to each student, which explained the following concepts in a step-by-step manner: ・ basic definition of probability and meaning of randomness; ・ random experiment and sample space; ・ probability of an event; ・ theoretical probability versus empirical probability of an event; ・ simulation. In the worksheet, each concept was followed by exercises, which enabled the students to explore the concept either by simulating an experiment on the calculator or by actually performing the experiment and recording the observations. Some exercises required by-hand calculations. ＊Concept of randomness An exercise required the students to generate numbers randomly in the RUN mode of the graphics calculator by entering the Ran# function, which produced a pseudorandom number between 0 and 1 each time EXE was pressed. The following exercise required students to generate 10 integers between 1 and 10 randomly and repeat this experiment 10 times, each time counting the number of integers greater than 5. This was done in the TABLE mode by entering Int(10×Ran# + 1) and setting the Range as 1 to 100. For this particular student, out of 100 randomly generated integers between 1 and 10, 54 were greater than 5. Different students obtained different answers. Combining the answers of the entire

	class revealed that the fraction of integers greater than 5 was very close to 1/2. I emphasised the relevance of this experiment, by explaining that the chances (or probability) of a randomly selected integer between 1 and 10, being greater than 5, was equal to 1/2. ＊Random experiment and sample space Having dealt with randomness, the concepts of random experiment, outcomes of a random experiment and sample space were introduced. The tossing of coin(s) and throws of a die were introduced as examples. An exercise required the students to write the sample space for the simultaneous toss of two, three, and four coins and to generalise by concluding that the number of outcomes for n coins is equal to 2n. A similar exercise required the students to make a generalisation for n die. All students were able to arrive at these generalisations without much effort. ＊Theoretical probability of an event The worksheet the theoretical probability of the occurrence of an event, E, was defined as, 'Number of outcomes favourable to the event E / Total number of outcomes in the sample space'. This was explained via various examples and an exercise required the students to compute the theoretical probabilities of events such as getting at least one tail in the toss of three coins or getting a sum of 7 in the throw of a pair of dice. ＊Difference between the theoretical and empirical probability of an event. After covering the theoretical definition, the difference between the theoretical probability and the empirical probability of an event was explained by citing the example of tossing a single coin where the theoretical probability of obtaining 'heads' is 0.5. As I explained however, tossing a coin 100 times may not result in exactly 50 'heads.' Instead one may obtain 47 heads, in which case the empirical probability of getting 'heads' is 0.47. I emphasized that although the empirical probability (also called 'relative frequency') gives the actual fraction of the total trials that result in the occurrence of an event, the theoretical probability gives the 'long-term' fraction of the total trials that result in the occurrence of that event. An exercise (designed to highlight this difference) required each student to perform the experiment of throwing a die 100 times and computing the empirical probability of obtaining a 1 (using the formula: Number of 1s /100). Further students were required to combine their results with those of four others in the class to obtain 500 throws in all and then to compute the empirical probability by successively adding the number of 1s obtained in each successive 100 throws. They were asked to record their observations in a table and plot the empirical probabilities versus the number of throws. ＊Simulation on the graphics calculator In a simulation experiment a large number of trials are generated and the relative frequencies of the required event are used to estimate the probability of that event. To estimate the probability of obtaining a 6 in the throw of a dice, for example, one could actually throw a die a large number of times and use the relative frequency of sixes (number of sixes / total number of throws) to estimate the probability or one could simulate the throws by generating the numbers 1 to 6, randomly using the Ran# function on the graphics calculator. ＊Simulation activities 1.Simulating the throw of a die An exercise required each student to simulate 100 throws of a die on the graphics calculator by randomly generating 100 integers from 1 to 6 in the TABLE mode by typing Int(6×Ran#+1), as shown in Figure 5. Once the integers were generated they were stored in the LIST mode and sorted. Having done this the students counted the number of 1s, 2s, 3s,

4s, 5s, and 6s and computed the outcomes' respective empirical probabilities. They appreciated the advantages of simulating the dice throwing experiment on the calculator since it took far less time than actually throwing the dice!

2. Simulating the toss of a pair of coins

Another exercise required students to simulate 100 tosses of a pair of coins by randomly generating 1s and 2s (1 for 'heads' and 2 for 'tails'). In the TABLE mode Int(2×Ran# + 1) was entered in Y1 and Y2. The numbers were stored in List1 and List2 respectively. In List3, 10 × List1 + List2 was entered. This generated a list of 11s (two heads), 12s, 21s (one head and one tail) and 22s (two tails). List3 was then sorted to make the counting easier. Students were asked to record their observations in a table.

3. Simulating the throw of a pair of dice

Students concluded that a sum of 7 could be obtained if the pair of die showed the combinations (1,6), (2,5), (3,4), (4,3), (5,2), and (6,1) (out of 36 possible combinations), leading to a theoretical probability of 1/6. 100 throws were simulated by entering Int(6×Ran# + 1) in Y1 and Y2 in the TABLE mode. This generated two lists of random integers between 1 and 6, which were stored in List1 and List2 respectively in the LIST mode. Students suggested storing List1 + List2 in List3, sorting and counting the number of sevens to compute the empirical probability of obtaining a sum of 7.

4. Simulating the birthday problem

The estimates provided an interesting range of group sizes. Some were as low as 15 whereas others were as high as 365 or 366! Only two students gave the correct answer 23 but no explanations were provided. In order to verify that the answer is indeed 23, each student was asked to write down ten different birthdays (of friends or relatives) on different slips of paper, which were folded and put in a box. Ten sets of 23 birthdays each were created from the contents of the box. Students working in threes were assigned one set each and had to check for a repeated birthday. Five groups out of 10 had at least one repeat (2 out of these had two repeats) the first time. This experiment was repeated twice. The second time 5 sets showed at least one repeated birthday and the third time 4 sets showed the same. This somewhat convinced the students that the probability of finding at least one repeated birthday in a group of 23 people was about half! The next step was to simulate the problem on the graphics calculator. Each student had to generate twenty-three birthdays randomly on the calculator using the following steps.

Step 1: Generate a list of 23 integers randomly between 1 and 12 (including 1 and 12) to denote the month by entering Int(12×Ran# + 1) in Y1 in the TABLE mode and setting the Range as 1 to 23.

Step 2: Generate a list of 23 integers randomly between 1 and 31 (including 1 and 31) to denote the day of the month by entering Int(31×Ran# + 1) in Y2 in the TABLE mode and setting the Range 1 to 23,

Step 3: Store the column Y1 into List1 and Y2 into List2. In the LIST mode, take the highlight to List3, and type 100 × List1 + List2. This converts all the dates to three or four digit numbers whose first one or two digits indicate the month and the last two digits indicate the day of that month. For example, 225 indicates 25 of February and 1019 indicates 19 October. Thus List3 is a list of 23 randomly generated birthdays. In case the list contains an impossible date such as 31 April, the entire list may be rejected and a new one may be generated. A more efficient method, however, is suggested at the end of this section.

Step 4: Sort List3 to check for matches. This ensures that the repeated dates appear one after the other.

	Each student was asked to run the simulation ten times and check for a match each time. In case of a match the repeated birthday was to be recorded. Most students obtained a match 5 out of 10 times! Certainly after this experiment the birthday problem became more believable to them! A simpler and perhaps more efficient way of simulating the birthday problem on the graphics calculator is to generate a list of 23 random numbers between 1 and 365 (representing the 23 birthdays) and sorting the list to check for a repeat. In this method each day of the year is identified by a number between 1 and 365 and there is no risk of obtaining an impossible date.
所收集之 研究資料	Questionnaire
研究結果	Some general comments on the lessons included the following. ・ ‘These lessons helped me to explore and understand the basic principles of probability.’ ・ ‘These lessons have been especially helpful in highlighting the difference between the empirical and theoretical probability of an event.’ ・‘Teaching this topic through the worksheet and via graphics calculators is a much better way of teaching than the regular classroom methods. It was real fun doing the experiments on the calculator.’ • The concept of simulation was entirely new to me. I realise its importance since it would be really tiresome to throw a coin or dice 1000 or more times and then compute the empirical probability.
科技工具之特點	1. Students were able to simulate experiments and arrive at results on their own. This gave them a sense of discovery. 2. The use of calculators made the lessons more interactive. Students gave their own suggestions and asked more questions than they would have in a traditional class. 3. The calculator helped to estimate the probability of an event by enabling the students to generate a large number of trials by simulation. It also helped to highlight the difference between the theoretical and empirical probability of an event.

編號:190

Data Extraction Form	
欄位名稱	內容
文獻來源	Wei, C. S., & Ismail, Z. (2010). Peer Interactions in Computer-Supported Collaborative Learning using Dynamic Mathematics Software. Procedia-Social and Behavioral Sciences, 8, 600-608.
研究目的	This study investigates peer interactions in terms of intervention styles and intervention strategies used by students in computer-supported collaborative learning (CSCL) using dynamic mathematics software. The following research objectives were investigated in this study: 1. To explore the intervention styles used by peers in computer-supported collaborative learning. 2. To explore the intervention strategies used by peers in computer-supported collaborative learning
研究問題	
研究方法	Experimental research design was conducted to investigate the intervention styles and intervention strategies that were used by peers in computer-supported collaborative learning. In the experiment, three pairs of 16 year old students participated, i.e. one female-female dyad, one male-male dyad, and one mixed-gender dyad. They were selected randomly from five secondary schools in Johor
教學單元	□數與運算(Number & Operations) ■代數(Algebra) ■幾何(Geometry) □測量(Measurement) ■資料分析與機率(Data Analysis & Probability)
教學主題	geometry, algebra, and statistics
教育階段	□國小 ■國中 □高中 three pairs of 16 year old students participated
融入教學之工具	Dynamic mathematics software: GeoGebra
學習活動 (Learning activity)	教學策略: Collaborative learning (this study was based on constructivist view of learning)
	The students worked on the dynamic mathematics software in a three-hour session for three days. Each experiment comprised three parts, i.e. introduction (about 10 minutes), collaborative work (about 2 to 3 hours) and discussion (about 10 minutes). During the experiment, each dyad sat in pairs to use a laptop together and took turns in using the keyboard and the mouse. GeoGebra was used as a cognitive tool, and Wink was used as a screen-casting tool while Microsoft Word was used as an editing tool. The frame-recordings, works in GeoGebra, and the answers of modules in Word were then utilized as artefacts collections. They discussed among themselves to carry out the tasks in the modules. There are three modules with 6 tasks for the participants to complete, i.e. geometry, algebra, and statistics. For all the tasks, students were required to construct the figure given by following step-by-step instructions, and then explore the properties of that figure by measuring, observing, and dragging. In geometry module, students had to create two tangents to a circle and examine the properties of two tangents to a circle. Furthermore, students were asked to reflect a picture and inspect the properties of reflection as well. In the algebra module, students had to construct a linear function and look into the properties of linear function. The students also had to create a quadratic function and investigate the properties of quadratic function. Statistics module was designed to let students to construct a histogram and explore the histogram.
所收集之研究資料	Video-recordings with a camera as well as audio-recordings with a voice recorder.
研究結果	The findings provide evidence for utilizing dynamic mathematics

	software in collaborative learning to enhance active interactions between the dyads. The transcripts of the students' interactions were coded into three intervention styles: 1. leading: students guided their partner by giving step-by-step explanation. 2. showing and telling: to inform their partner new information regardless of the accuracy. 3.shepherding: including completing sentences, questioning, paying attention to the other's comments, giving feedback, and adding ideas. ＊eight intervention strategies: 1.checking：check their work. 2. reinforcing：student repeated the finding of the partner in the interaction. 3.inviting：was used to invite partner to find out new idea. 4.enculturating：student exploited the enculturating strategy to correct their partner in terms of terminology. 5.blocking：student blocked their partner from doing mistake. 6.modeling：students model their own thinking. 7.praising ：students used praising strategy to praise themselves when working something out successfully. 8.rug-pulling: ask their partner to reexamine something that was confusing.
科技工具之特點	1. In general, they showed their partner by pointing to the figure in the GeoGebra interface and the changes of the figure in the GeoGebra. Such situation showed that GeoGebra can be used as visual aids to help students to better understand certain mathematics concept. 2. Generally, they adopted the checking strategies when they are confused about something. They always refer to figure in GeoGebra interface to check their answer to determine whether their answer is true or otherwise.

編號:204

Data Extraction Form	
欄位名稱	內容
文獻來源	Yang, D. C., & Tsai, Y. F. (2010). Promoting Sixth Graders' Number Sense and Learning Attitudes via Technology-based Environment. Educational Technology & Society, 13 (4), 112–125.
研究目的	Investigate the effect of integrating technology into mathematics teaching on students' number sense and their learning attitudes.
研究問題	1. Is there a significant difference in students' learning of number sense between students whose teachers use technology and students whose teachers do not use technology? 2. Is there a significant difference in students' mathematics attitudes towards learning number sense between those who use technology and those who do not use technology?
研究方法	A quasi-experimental design. Control group students followed the general instruction without using technology；Experimental group students learned number sense in a technology-based environment.
教學單元	■數與運算(Number & Operations) □代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	Number Sense: Understanding of fractions、understanding of equivalent fractions.
教育階段	■國小 □國中 □高中 Two sixth-grade classes were selected from an elementary school
融入教學之工具	Web-based learning resources: Several different resources used in the experimental group classroom to integrate technology into the number sense teaching were described as follows: (1)The Website http://nlvm.usu.edu was used to allow the students to manipulate the pictorial representation of fractions to help them develop a better understanding of fractions. (2)The Website http://163.30.150.88/lii/flashMath/index.htm was used to help students develop a better understanding of equivalent fractions. (3)Based on the number sense activities, a computer specialist was invited to design the related activities by using the program of visual basic, such as cif_01.exe and cif_02.exe.
學習活動 (Learning activity)	教學策略: 小組討論（work together in small groups to discuss） The pictorial representation via technology-based environment was integrated into the experimental class: First, children open the file (cif_01.exe or cif_02.exe), when children were asked to enter and draw the fractions. At this moment, children could work together in small groups to discuss the relationships, when children could overlap the pictures to see what happens.
所收集之研究資料	A Web-based two-tiered test on number sense before (pretest) and after (posttest)、The Survey of Attitudes Towards Mathematics Learning
研究結果	量化: The ANCOVA results showed a statistically significant difference between the control group and the experimental group on number sense performance. The t- test results showed no significant difference before and after the instruction for the control group. However, there was a statistically significant difference before and after the instruction for the experimental group. Furthermore, data also showed a significant difference in the students' learning attitudes between the control group and the experimental group after the teaching. These results indicated that integrating technology into number sense teaching and learning not only promote students' number sense, but also has a positive effect on

	attitudes towards learning number sense.
科技工具之特點	1. 圖像表徵：the pictorial representation via technology-based environment is easy and convenient for teachers to manipulate and demonstrate the mathematical concepts. 2. 互動性：the technology assisted in allowing students in the experimental class to interact with the mathematical concepts in novel ways. →It promoted the students in the experimental class to develop number sense through manipulating the pictorial representation. 3.there are several benefits for teaching and learning mathematics concepts via a technology-based learning environment: (1)Drawing the graphs by computer can be done more easily. (2) Visual representations can attract the students' attention. (3)Overlapping and separating the graphs can be more efficiently and conveniently accomplished by the computer.

編號:237

Data Extraction Form	
欄位名稱	內容
文獻來源	Bai, H., Pan, W., Hirumi, A. & Kebritchi, M. (2012). Assessing the Effectiveness of a 3-D Instructional Game on Improving Mathematics Achievement and Motivation of Middle School Students. British Journal of Educational Technology, 43(6), 993-1003.
研究目的	the purpose of this study was to explore the effectiveness of DimensionM, a 3-D mathematics instructional game, for improving student achievement in algebra at middle school levels .
研究問題	1. Did DimensionM improve eighth graders' algebra achievement scores? 2. Did DimensionM increase eighth graders' motivations in mathematics learning?
研究方法	1. A pretest–posttest control group quasi-experimental design. 2. The treatment group: worked with DimensionM in computer labs to supplement the regular classroom instructions；the control group received the classroom instructions with regular class activities without computer aids. the DimensionM game during this experimental period of 18 weeks.
教學單元	□數與運算(Number & Operations) ■代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	DimensionM included mathematics topics in algebra aligned with the eighth grade curriculum.
教育階段	□國小 ■國中 □高中 437 eighth graders
融入教學之工具	DimensionM game：3-D mathematics games
學習活動 (Learning activity)	教學策略: All teaching conditions for treatment and control Groups were similar in terms of the mathematics topics, access to resources such as textbooks and additional library books, and school environment. The only difference was that the treatment group used the games as supplement to further practice topics taught by the teachers.
所收集之 研究資料	posttest–pretest
研究結果	1.The results of the analysis on the pretest–posttest data revealed that the DimensionM game increased mathematical knowledge acquisition in algebra and maintained student motivation to learn. The findings suggest that the implementation of DimensionM in mathematics education can greatly benefit middle school students learning algebra. 2.The multivariate and univariate tests revealed significant differences between the treatment and control group in the gains of mathematics achievement scores and motivation scores, with the treatment group having significant higher gains in mathematics achievement scores and motivation scores. Considering the gain score differences, we can see that the treatment group had significantly higher gain scores in the benchmark test scores and the motivations.
科技工具之特點	1.This study provides the empirical evidence that DimensionM can offer students the opportunity to (1) open and then experience the mathematics knowledge bank, (2) absorb the knowledge through interactions with the real world problems. →Findings from this study suggest that DimensionM can improve mathematics achievement at middle school levels and it also helps to sustain student motivation to learn.

	2. DimensionM teaches mathematics concepts indirectly and within a play context. Such a positive achievement effect can be attributed to the game incidental learning approach. 3. the positive effect of the game in increasing mathematics motivation of students can be related to its adoption of three elements of arousal, direction and persistence

編號:650

Data Extraction Form	
欄位名稱	內容
文獻來源	Kong, S. C. (2011). An evaluation study of the use of a cognitive tool in a one-to-one classroom for promoting classroom-based dialogic interaction. Computers & Education, 57(3), 1851-1864.
研究目的	The evaluation study was aimed at investigating whether a learning environment that integrated the use of the GPM and the one-to-one classroom setting could lay a foundation for promoting classroom-based dialogic interaction in mathematics lessons that supports students in generating conceptual and procedural knowledge of common fractions.
研究問題	(1) How does the use of the GPM in a one-to-one classroom affect student engagement, in terms of time-on-task, in learning about common fractions? (2) How does the use of the GPM in a one-to-one classroom affect student attainment in learning about common fractions? (3) How do students perceive the use of the GPM in a one-to-one classroom for learning about common fractions?
研究方法	This study considered that time-on-task was most reflective of the degree of student engagement in classroom learning. Time-on-task in this study refers to the actual time that students engaged in the cognitive growth of conceptual understanding and procedural knowledge related to common fractions through productive interaction with the GPM, learning materials such as worksheet, workbook or textbook, or other classmates in the learning tasks. In this time allocation analysis, the time allocated for class activities in each teaching session for the experimental and control groups was analyzed and compared. Video recordings and lesson observation were made in each of the 22 teaching sessions delivered over the course of the teaching period. The classroom video clips and lesson observation records were reviewed for further classification of class activities. Table 4 lists the categories of class activities undertaken during the teaching sessions delivered in this study. The time allocated for each category of class activities undertaken during the teaching period was calculated across the experimental and control groups.
教學單元	■數與運算(Number & Operations) □代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	the learning of common fractions
教育階段	■國小 □國中 □高中 Primary 4 students who aged 9–10
融入教學之工具	A computer-supported cognitive tool (CT) called the "Graphical Partitioning Model"(GPM)(The GPM is a graphical model in the form of a rectangular bar with a partitioning/regrouping function.)
學習活動 (Learning activity)	教學策略:
	In the teaching sessions for the experimental group, students learned the target topic using the GPM in a one-to-one classroom setting. Tablet PCs were used in class, because every student in the experimental group owned a tablet PC with a wireless connection to the Internet for classroom learning. The learning materials for the experimental group included the GPM along with a set of GPM activity worksheets, a set of school-based worksheets, and the school-based workbook. The GPM activity worksheets included a number of tasks designed for guiding students to compute fraction operations. A number of discussion questions were also included in the GPM activity worksheets according to the learning needs related to the target topic. These discussion

	questions, not compulsory for completion, aimed at promoting students to discuss target knowledge with peers for a better understanding of the target topic. During class time, students were asked to access the GPM online using their own tablet PCs. The GPM activity worksheets and the school-based learning materials were distributed to the students according to the learning flow. Students were asked to complete the tasks in the learning materials using the GPM in the classroom. A total of 292 questions were assigned to students over the course of the teaching period.
所收集之 研究資料	Video recordings、lesson observation、pre-test and a post-test、A questionnaire survey.
研究結果	1. Impact of the designed learning environment on student engagement in terms of time-on-task →In summary, the designed learning environment enabled the teacher to deploy a more learner-centered approach in arranging class activities. The results of the time allocation analysis show that using the GPM in a one-to-one classroom increased time-on-task of students, and therefore their engagement in learning about common fractions. The teacher whose students learned with the GPM in a one-to-one classroom reduced nearly 30% of class time for teaching but increased three times the class time for student activities, comparing the teacher whose students learned the target topic under traditional teaching approach. It is possibly because the designed learning environment supported students in independently generating knowledge and solving problems related to the target topic at their own learning pace, and therefore allowed the teacher to provide more learning autonomy for students to engage in learning exploration. 2. Impact of the designed learning environment on student attainment. →In summary, the results of the attainment tests show that using the GPM in a one-to-one classroom enhanced student attainment in learning about common fractions. The designed learning environment therefore meets another criterion for the successful promotion of classroom-based dialogic interaction in mathematics lessons it enhances student learning performance 3. Student perceptions of the designed learning environment. →The students' overall perception of the GPM was positive. They agreed that the GPM assisted them in learning about common fractions and developing a greater understanding of the target topic. Many students felt they liked mathematics more after using the CT for learning. They also showed interest in continuing to use the GPM to support their learning. A large number of the students expressed their willingness to introduce the CT to other schoolmates. The overall results of the questionnaire survey show that the students regarded the use of the GPM in a one-to-one classroom to learn about common fractions in positive terms. The designed learning environment therefore meets the third criterion for the successful promotion of classroom-based dialogic interaction in mathematics lessons it is positively perceived by students.
科技工具之特點	1.The GPM provided three main types of scaffolds：visual representation, graphical manipulation, and immediate feedback to support learners in generating knowledge of the target topic by their own without teacher mediation. (1) The GPM provided a graphical manipulation for fraction comparison with immediate feedback on equivalence status. When a learner input multipliers for the numerator and denominator of a fraction expression to test for possible fraction equivalence, the GPM enabled the learner to drag a fraction bar and drop it onto another bar to trigger an animation directly comparing the equivalence of the two fraction bars. (2) Immediate feedback was then displayed to advise on fraction

	equivalence. This allowed learners to clearly visualize the quantity of fraction value based on accurate graphical representations. 2.學習活動中科技工具益於學習的原因 (1)For the tasks on learning how to convert between an improper fraction and a mixed number, the GPM offered a graphical manipulation of the conversion process with immediate feedback on answer explanation. When a learner input an improper fraction to find its form as a mixed number or vice versa, the GPM enabled the learner to double-click the fraction bar to toggle its graphical representation between the improper fraction and mixed number forms. Immediate feedback was then displayed to explain the naming and concepts of the two forms. This allowed learners to connect their conceptual and procedural knowledge of conversion between improper fractions and mixed numbers. (2) For the tasks on learning how to add/subtract fractions, the GPM offered a graphical manipulation of fraction operations with immediate feedback on answer correctness. When a learner input two fraction expressions to find their sum or difference, the GPM enabled the learner to choose between an automatic animation and a manual action to move the fractional parts in one fraction bar to another bar and complete the addition/subtraction process. This allowed learners to directly experience and clearly visualize the fraction addition/ subtraction process. Immediate feedback was then displayed to advise on the correctness of the final solution. This supported learners by alerting them to possible errors in their fraction operation processes. (3)For the tasks on learning how to simplify fraction forms, the GPM provided a graphical manipulation of fraction simplification with immediate feedback on answer correctness. When a learner selected a fraction expression to find its simplest form, the GPM enabled the learner to click on the selected fraction bar and check a list of common factors for fraction simplification. An animation for regrouping fractional parts followed when the learner selected one of the common factors.

編號:660

Data Extraction Form	
欄位名稱	內容
文獻來源	W Y Hwang, N S Chen, R L Hsu. (2006). Development and evaluation of multimedia whiteboard system for improving mathematical problem solving. Computers and Education, 46(2), 105-121.
研究目的	The objective of this study is to develop a multimedia whiteboard system and evaluate students acceptance and satisfactory use of the system for learning mathematics. In addition, students learning performance and their ability of mathematic problem solving are also investigated.
研究問題	
研究方法	The research design for peers communications divided into two phases： 1. the first phase was for peer comment and defending each others solutions. 2. the second phase was for students to justify a correct solution from three possible solutions to a math problem and explain why they thought it was right.
教學單元	■數與運算(Number & Operations) □代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	The topic of fractional division learning
教育階段	■國小 □國中 □高中 38 sixth grade elementary school students
融入教學之工具	The multimedia whiteboard system.
學習活動 (Learning activity)	教學策略: Students were first giving two weeks tutorials to learn how to use the multimedia whiteboard system. After that, math problem solving activities were then conducted. During the experiment, instructors gave one math problem every week and asked students to solve it with the multimedia whiteboard system. ＊Peers communications divided into two phases. All math problems solving and assessment processes such as calculations, critiques(評論) and refutations made by students were automatically recoded. Here “Critiques” are comments that students made about others solutions by employing the multimedia whiteboard system. Students were given some math problems, and each problem was provided with several different solutions but only one was correct and others were wrong. Every student was asked to choose a right answer and used the multimedia whiteboard system to explain why he/she thought it was right and how it worked. “Correctly justified” means a student can correctly judge the right answer by doing a correct calculation process, meanwhile “correctly explained” means a student can also explain the reason why he/she thinks the solution should be a correct one.
所收集之研究資料	Questionnaire、the content of students comments and feedbacks are classified and quantified into different classes.
研究結果	The results show that students were satisfied with the use of the multimedia whiteboard system for helping them with learning fractional division. Most students were interested in studying mathematics with the multimedia whiteboard system and thought this tool is particularly useful for doing collaborative learning. After analyzing the recorded solving processes and discussions content of students, we found that the performance of female students was superior to male students in communications and mathematical problem solving. Additionally, students with higher final exam grades had better mathematical abilities for doing critiques, arguments and communications.

	＊量化資料：(問卷) 1.Survey on perceived usefulness and ease-of-use： (1) That most subjects agreed the functions and user-interface of the multimedia whiteboard system were useful and easy to use. (2) Most users also responded positively that the designed multimedia whiteboard system was very helpful for them to solve math problems. (3) Majority of subjects agreed that they could become skillful at writing mathematical symbols, calculation procedures and oral explanations using the tools provided by the multimedia whiteboard system. 2. Survey on satisfaction on mathematical problem solving and peers communication： (1) Most subjects agreed that the multimedia whiteboard system could satisfy the needs of math problem solving and peers communication. (2) The multimedia whiteboard system could help students to easily express logic reasoning and clearly explain solving processes for their math solutions. (3) The system can also support peers to do suggestions or comments on each other's solutions. Based on students higher agreements on these items, we are confident that the system can improve students mathematical problem solving ＊質性資料：Through this kind of iterative communication, many correct responses to others comments or queries were derived.(about mathematical critiques and refutations) 1. It shows the diversity of approaches to solve the kind of math problems. Some students used the strategy of setting divisor and dividend to have the same denominator and next divide the numerator of dividend by the numerator of divisor to get the solution 2. Other students used the strategy of multiplying dividend by reversed divisor to solve the problem 3. Most of students employing the strategy 2(Multiply reversed divisor to get the solution) cannot clearly explain the algorithm of multiplying reversed divisor, that is to say they do not understand why dividend that is divided by a fraction can convert to multiply the reciprocal of the fraction.
科技工具之特點	1. The multimedia whiteboard system is just amusing. It is easy to record oral explanation such that others can easily understand the thinking of your solutions. 2. The multimedia whiteboard system, supporting a text discussion board with file attachment, an electronic whiteboard and a voice recorder, has demonstrated a useful tool for learning mathematical fraction problems 3. Students are interested in and enjoy the discussion in the multimedia whiteboard system as it allows them to express their thought through text, images, voice and electronic whiteboard. 4. The multimedia whiteboard system provides electronic whiteboard for writing symbols and voice recorder for oral explanations to facilitate peers interactions and communications, such that students can easily and effectively discuss math topics with peers; their mathematical abilities are then enhanced.

編號:669

Data Extraction Form	
欄位名稱	內容
文獻來源	Hauptman, H. (2010). Enhancement of spatial thinking with Virtual Spaces 1.0. Computers & Education, 54(1), 123-135.
研究目的	This paper also reports on a study that aimed to assess whether those abilities affected achievements in the spatial thinking of 10th graders who worked with the software. Additionally, we investigated whether self-regulating questions can improve the effect of exercising with Virtual Spaces 1.0.
研究問題	Two questions: 1. Is it possible to advance spatial thinking by employing Virtual Spaces 1.0? 2. To what extent does the addition of SRQ to the exercises in Virtual Spaces 1.0 contribute to the advancement of spatial thinking? Hypotheses were formulated: 1. Students who learn with Virtual Spaces 1.0 will receive higher grades on tests of spatial thinking than those who learn without Virtual Spaces 1.0. 2. Students who practice with Virtual Spaces 1.0 and SRQ will receive higher grades on tests of spatial thinking than those who practice without SRQ(Self-Regulating Questions).
研究方法	To evaluate two experimental interventions (VR and SRQ) not only separately, but also in combination and against a control group, the current study utilised a pre-test–post-test 2 2 design.
教學單元	□數與運算(Number & Operations) □代數(Algebra) ■幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	Spatial thinking
教育階段	□國小 □國中 ■高中 194 tenth-grade students in six comprehensive high schools
融入教學之工具	Virtual Spaces 1.0 software：was designed specifically for this study, is a software environment based on the technology of immersive virtual reality, which merges elements of teaching with PCs (the use of textual feedback) with the advantages of virtual reality (the manipulation of objects that are not on a flat screen). This version of Virtual Spaces 1.0 is designed as an exercise environment that includes 52 exercises, and not as a constructing tool for studying geometrical objects.
學習活動 (Learning activity)	教學策略: Group 1 (N = 52): practiced with Virtual Spaces 1.0 and SRQ. Group 2 (N = 52): practiced with Virtual Spaces 1.0 but without SRQ. Group 3 (N = 45): practiced from a booklet with the same exercises as Group 1 and with SRQ. Group 4 (N = 45): non-treatment group practiced from a booklet the same exercises as Group 1 but without SRQ. The research took place in five comprehensive schools over a period of five months. Each school chose a day of the week, and on that day, we summoned students to the computer lab there they did exercises with Virtual Spaces 1.0 (Groups 1 and 2) or worked on the same exercises in booklets (Group 3 or Group 4) in vacant classrooms. The hours schools allotted were 12:00–16:00. During these hours, each student in Groups 1 and 2 worked with Virtual Spaces 1.0 for 15 min a day for 3 weeks. In the first week all the students were tested on MRT and APTS-E. In the next 2 weeks the researcher met with the participants of Groups 1 and 2, and a short presentation of the new technology (the stereoscopic 5DT

	HMD and the three-dimensional mouse) was given. Each student put on the HMD and was shown how to fasten the plastic bands to fit his or her head and then practiced for 5–12 min, navigating in the ‘‘world of concepts’’ and the usage of the manipulating tools. During the next 15 weeks, students in Groups 1 and 2 finished doing exercises with Virtual Spaces 1.0 at the same time that students in Groups 3 and four finished their exercises in their booklets. They studied with a teacher who explained the instructions for each exercise and asked the students to solve the exercises. After two lessons they finished all the exercises. In the 19th week, all the students were tested again on MRT and APTS-E. In the 20th week, the researcher met with students and thanked them for their efforts.
所收集之 研究資料	Spatial-Visual Reasoning test of the Aptitude Profile Series - Educational (APTS-E)、Vandenberg & Kuse Mental Rotation Test (MRT).
研究結果	The results suggest that spatial thinking was enhanced by exercising with Virtual Spaces 1.0 and asking self-regulating questions. In addition, it was found that the self-regulating questions make the use of virtual reality more efficient, and that the influence of self-regulating questions is especially manifested in tasks that make use of high order skills. The first hypothesis was that the achievements of the students who practiced with Virtual Spaces 1.0 and SRQ would be higher than that of students who practiced without this combination. Findings show that the achievements of Group 1, who practiced with Virtual Spaces 1.0 and SRQ, were higher than those of Group 2, who practiced with Virtual Spaces 1.0 but without SRQ, but the difference was not significant. Since the APTS-E test is more complex than the MRT test, we considered the possibility that the findings could indicate that SRQ contributes more than VR for more complex tasks, while for simpler tasks the SRQ is less effective. The findings indicate that practice with Virtual Spaces 1.0 is more effective for advancing spatial thinking than the conventional method. The use of VR becomes more efficient with SRQ in carrying out complex tasks.
科技工具之特點	The unique nature of this study’s findings expresses itself in a number of areas. 1. They indicate a significant improvement of achievement in the nonverbal aspect of spatial thinking due to the special visual effects of virtual realty learning environments. Additionally, the improvement in the verbal aspect of spatial thinking can be explained by the activating of verbal processes in the creation and manipulation of spatial images, which occurred in the asking of self-regulating questions. 2. They enhancing the processes of creating and manipulating a spatial image is a basic condition for advancing spatial thinking.

編號:671

Data Extraction Form	
欄位名稱	內容
文獻來源	Baki, A., & Güveli, E. (2008). Evaluation of web based mathematics teaching material on the subject of functions. Computer and Education,51, 854–863.
研究目的	The main purpose of this mixed methods study is to examine the effects of WBMT material on levels of achievement of 9th grade students in basic concepts of functions taking place in high school mathematics curriculum and attitudes towards WBMT.
研究問題	The question ‘‘How would the holistic web based mathematics teaching material on functions be accepted which has been brought about by the technological advances and which is used almost anywhere on the computers for the purpose of secondary school education and through the assistance of appropriate computer software?’’ has been chosen as the main research question of this study. Sub-problems: 1.Teachers: (1)How did they exploit the WBMT material? (2)How were their attitude and approach towards WBMT and its future? (3)How did they evaluate WBMT material? 2.Students: (1)What was their attitude and approach towards the WBMT material? (2)Do they improve their level of achievement in mathematics by engaging with WBMT? (3)How did they evaluate WBMT material?
研究方法	An experimental method was considered as appropriate to this study to investigate the effect of WBMT material on student success compared with the traditional method. As the control and experimental groups were not formed randomly, semi-experimental method was used. Some data was compiled by action research method in the determination of what kind of teaching-learning environment was achieved when WBMT is used. As WBMT approach is a new and different from the traditional education system, action research method was chosen because of the need to introduce this approach and to compile data during its implementation. While the control group continued their lessons with traditional methods, the experimental group was taught by using the WBMT material.
教學單元	□數與運算(Number & Operations) ■代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	The topic includes general concept of function, definition of function and different representations of function.
教育階段	□國小 ■國中 □高中 eighty 9th grade students
融入教學之工具	Web-based mathematics teaching (WBMT) material (WBMT materials including well organized small sequenced tasks. These tasks were supposed to allow for drill and practice and lead to the mastery of skills)
學習活動 (Learning activity)	教學策略: Students in the experimental group were taken into a computer lab for two hours per week. They practiced with WBTM material in addition to the regular lectures on the topic under the guidance of the teacher. Thus, students had approximately 10 hours of computer lab within the fall term. In addition to this period of time, students in the experimental group reached the material through internet in their spear time out of the school.

所收集之 研究資料	Attitude scale, interviews, field observations、pre-assessment test、post achievement test.
研究結果	The analysis of the data suggests positive effect of WBMT on student learning of mathematical function and on attitudes towards WBMT. However, the teachers all represented and shared some common ideas that because of the technical problems and readiness of teachers and students there would be some problems in terms of successful implementation of WBMT in schools. Nevertheless, the results provide support for the use of this WBMT material as a complement to traditional classes. 1. Overall, most of the students in experimental group enjoyed the new learning experience and opportunity. 2. Students that used WBMT material as complement to class lectures improved significantly more than those that just had traditional class lectures. 3. Students' final evaluation and observation notes showed that students who were used WBMT material showed higher level of satisfaction. As students became more familiar with mathematical processes and online procedure, they become more confident in their learning. They appeared to be highly motivated and presented their feelings very openly and clearly
科技工具之特點	1. It was found that WBMT material enabled a more appropriate use of scaffolding for student learning. Exercises and tasks in site were divided into appropriate learning steps including concept presentation, sufficient examples, hints and interactive exercises with immediate feedback. Using WBMT, students could read, practice and review the content as long as and as many time as, they wanted. 2. WBMT material includes exercises such as presenting functions in one of the representations and the students are asked to complete the other representations. There is a "Next" button provides new examples or exercises when it is pressed. For example, when it is pressed in the page of the equation and graph representation, it picks the y intercept and the slope of the line randomly and allows the students to practice as much as they like. 3. These findings suggest that WBMT can be used more effectively as a scaffolding for students. Students liked visual examples of WBMT material explaining step-by-step process. This aspect of the material allowed students have clear connections to what they were learning. 4. The findings show that self-experimentation with WBMT material helped improve the students' understanding of the concept of function and explaining the concept behind each representation of function.

編號:672

Data Extraction Form	
欄位名稱	內容
文獻來源	Lai, K., & White, T. (2012). Exploring quadrilaterals in a small group computing environment. Computers & Education, 59(3), 963-973.
研究目的	A primary motivation for the present study is to investigate the premise that working in small groups might be a particularly effective way to engender opportunities for students to engage in active exploration of and social interaction around geometric shapes.
研究問題	1. Do small group tasks involving the joint manipulation of quadrilaterals in a dynamic geometry environment support students' learning about geometric shapes and their relationships? 2. How do students interact and participate in small group activities involving the joint manipulation of quadrilaterals in a dynamic geometry environment?
研究方法	We conducted a six-day design experiment with three groups of four students who consented to be videotaped. All the students were either sixth or seventh graders, and were organized in groups based on their teachers' recommendations about which students they thought would work well together.
教學單元	□數與運算(Number & Operations) □代數(Algebra) ■幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	The students had to learn the following terms: quadrilateral, rectangle, square, parallelogram, rhombus, trapezoid, and kite.
教育階段	□國小 ■國中 □高中 sixth or seventh graders
融入教學之工具	NetGeo computer and graphing calculator environment
學習活動 (Learning activity)	教學策略: Students' learning sessions with the NetGeo environment spanned six days, including two days with each version of the computer and calculator interfaces described above, and correspondingly different sets of activities.
所收集之研究資料	There were four main data sources: 1. Pre- and post-assessments 2. Video recordings of work sessions 3. Field notes and design notes taken after sessions 4. Video capture of computer screen and logs of students' inputs
研究結果	Our study found that students achieved learning gains in this novel environment, that the environment provided rich opportunities for peer interaction around geometric objects, and that student learning opportunities and interactions were characterized by processes of appropriating ways of talking about and using software features. 1. First research question, we analyzed the students' pre- and post-performances on the quadrilateral assessment and also the quadrilateral sorting task. 2. Second question, we analyzed the group members' interactions during the activities, which involved analyzing recordings of the work sessions, looking over field notes taken during and after sessions, and also analyzing the video capture of the shared computer screen. We analyzed the video recordings of the students working together in conjunction with the screen video capture. We also noted students' gaze and gestures in the analysis.
科技工具之特點	1. An intended goal of introducing the NetGeo with Calculator Value Displays variation was that the students would use the information

	on the calculator screens as resources for completing the tasks and as means for verbalizing their ideas. 2. The learning environment supported students' development of their geometric reasoning as the students attended to the monitors, which made explicit the shapes' properties, allowing the students to relate these properties to the shapes and to articulate these properties. Students to deepen their understanding of essential and non-essential components of shapes, which is the beginning to understanding hierarchical relationships between shapes.

編號:688

Data Extraction Form	
欄位名稱	內容
文獻來源	Kramarski, B, & Gutman, M. (2006). How can self-regulated learning be supported in mathematical e-learning environments? Journal of Computer Assisted Learning, 22(1), 24–33.
研究目的	The purpose of the study is threefold: 1. To investigate the ability to solve procedural tasks of students who were exposed either to the EL1IMP or EL instructional approach. 2. To examine the ability to solve transfer tasks regarding mathematical explanations of students who were exposed to these instructional approaches. 3. To compare the differential effects of both approaches on SRL regarding strategy use and self -monitoring.
研究問題	1. How can SRL (self-regulated learning) be supported properly in a mathematical problem-solving environment？ 2. What characteristics should a SRL approach have in promoting and sustaining mathematical problem solving?
研究方法	This study compares two E-learning environments: E-learning supported with IMPROVE self-metacognitive questioning (EL1IMP), and E-learning without explicit support of self-regulation (EL). The effects were compared between mathematical problem-solving and self-regulated learning (SRL).
教學單元	□數與運算(Number & Operations) ■代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	Linear function
教育階段	□國小 □國中 ■高中 Participants were 65 (boys and girls) ninth-grade students who studied in two classes within one junior high school in central Israel.
融入教學之工具	E-learning：Excel、e-mail
學習活動 (Learning activity)	教學策略：SRL(self-regulated learning)
	＊The instructional approaches were as follows: (a) E-learning supported by the IMPROVE self-metacognitive questioning approach (EL1IMP) (b) E-learning without an explicit SRL approach (EL). ＊E-learning environments: EL1IMP vs. EL Students in both environments practiced 10 problem solving interactive tasks that were developed in Excel by the co-author of the study and were accessible to the students on the website. The tasks covered similar tasks and exercises as those presented in the textbook, but emphasized the unique components of each environment. Students were asked to practice in pairs, to solve the tasks, and send the solutions by e-mail to the teacher (because of the odd number of the EL1IMP environment students (n535), one group did not consist of a pair). The teacher encouraged students to participate in E-learning, explained its effects on problem solving, and provided support and feedback according to the instructional approach taught in the class. The tasks were accessible to the students on the website. Students were asked to solve the tasks and send the solutions by e-mail to the teacher. During the practice of the unit, students in EL1IMP environment were supported with the IMPROVE method in three aspects: (a) self-metacognitive questioning; (b) mathematical explanations; and (c) E-learning metacognitive feedback. Whereas students in the EL environment were not exposed explicitly to self-regulation

	activities. They were exposed to a computer-generated result feedback.
所收集之 研究資料	The study utilized two measures for the pre-test and posttest: (a) mathematical test; and (b) SRL questionnaire. (The study utilized two measures for the pre-test and post-test: mathematical test and SRL questionnaire. The mathematical test assessed students' procedural and transfer knowledge, and mathematical explanation ability. The SRL questionnaire assessed students' problem-solving strategy use and self-monitoring ability.)
研究結果	Promote and sustain mathematical problem solving? The results showed that students exposed to the IMPROVE self-metacognitive questioning in E-learning (EL1IMP) significantly outperformed the EL students in problem solving (procedural and transfer tasks) and mathematical explanations, in particular for providing mathematical arguments. We also found that the EL1IMP students outperformed their peers in using self- monitoring strategies but not in the use of problem-solving strategies. Further analysis indicated significant correlations between using self-monitoring strategies and mathematical performance on transfer tasks and mathematical explanation in the whole groups and particulary in the EL1IMP group. 1. The primary purpose of our study was to investigate students' procedural problem solving. →But on the post-test, we found significant differences between the instructions. EL1IMP students' outperformed the EL students in solving procedural tasks. 2. The second purpose of our study was to examine students' ability to solve transfer tasks regarding mathematical explanations. →Findings indicated significant differences on solving transfer tasks for the main effect for time and for the interaction between instructions and time. Effect-size indicated that at the end of the study the EL1IMP students outperformed the EL students on problem solving of transfer tasks. 3. The third purpose of our study was to compare differences in SRL regarding strategy use and self-monitoring. → The findings indicated significant correlations between using self-monitoring strategies and performance on transfer tasks and mathematical explanation in the whole group and in the EL1IMP group, whereas in the EL group significant correlations were found only with providing mathematical explanations. No significant correlations were found between using self-monitoring strategies and performance on procedural tasks
科技工具之特點	There are possible reasons for the beneficial effect of EL1IMP. 1. It seems that the IMPROVE approach might help students: access and interact with the content functionality, think about the deeper concepts and structure of disciplinary relations, and avoid superficial details. Making disciplinary strategies explicit in E-learning with IMPROVE tools can help students to think about the steps they need to take in their work, and help their thinking become explicit.

編號:701

Data Extraction Form	
欄位名稱	內容
文獻來源	Harskamp, E., & Suhre, C. (2007). Schoenfeld's problem solving theory in a student controlled learning environment. Computers & Education, 49(3), 822-839.
研究目的	In this paper we report on the development and evaluation of a computer program based on Schoenfeld's theory of problem solving and his ideas about adaptive hints to help students solve a mathematics problem. The program offers a student controlled learning environment with instructional hints for each episode in problem solving and with different solution methods to choose from within each hint. By offering different hints based on informal and formal solution methods all students can choose a level of instruction that can support them effectively. The main objective of the study was to assess whether students' problem-solving skills can be enhanced by means of an adaptive computer program based on Schoenfeld's theory of problem solving.
研究問題	1. Do students actually use hints on different episodes during problem solving? 2. During which episodes are these hints most effective? 3. Does a computer program according to Schoenfeld's theory of episodes help students to become better problem solvers?
研究方法	A pre-test–post-test quasi experimental design study.
教學單元	□數與運算(Number & Operations) ■代數(Algebra) □幾何(Geometry) □測量(Measurement) ■資料分析與機率(Data Analysis & Probability)
教學主題	period 1: Pre-calculus; rehearsal at the beginning of the year; period 2: Introduction to Functions and Graphs, Functions and derivatives, Exponential functions period 3: Periodical functions, Probability and Inferential statistics
教育階段	□國小 □國中■高中 pre-university classes, aged 15–17
融入教學之工具	Computer
學習活動 (Learning activity)	教學策略: 1. Experimental computer program group worked on 35 problems presented by the computer during three periods of two consecutive weeks. 2. All students received instruction on these topics from their teacher and used their textbook to get basic knowledge. In order to practice the application of knowledge the students in the experimental condition had to solve problems from the computer program. 3. Each week students in the experimental condition would fill out a form with their solution approach to one of the assigned problems. The teachers checked this work. The students used the computer program after they had received instructions from their teachers and covered basic exercises from the textbook. The book offers examples of solution methods in which procedures with tables and graphs are first introduced and algebraic procedures in a later stage.
所收集之研究資料	Pre- and post-tests
研究結果	The results show evidence of intervention effectiveness. The students who worked with the computer program showed increased problem-solving ability compared to the students in traditional mathematics instruction. The use of hints could explain an essential part of the increase in students' problem solving skills.

	1.The first question to answer is whether students actually used hints on different episodes during problem solving →students on average succeeded to solve 84% of the available 35 problems in the one to three attempts allowed. They fairly often made use of the available hints. It can be seen that students used hints more often with an informal approach (e.g. table or graph) to the problems than with a formal approach (solving equations). 2. The second question raised in this paper is whether the hints students used in different episodes to solve problems, are helpful in improving their problem-solving skills. →This signifies that students who often use hints during one episode also do so during other episodes. Especially the use of hints concerning the episodes Plan (make a solution plan) and Verify (checking model answer) correlates with post-test scores. The negative relationship between number of correct answers and the hints on Verify show that students do not always exploit the program fully. As a result high-skilled students score somewhat lower on the post-test than they would have, if they had used all available information on the correct solution procedure. This means that although the program in itself seems effective, some students use the program more effectively than others do. 3. The next question is whether the hints in different episodes are equally effective. →The expectation that especially hints for the episode Plan and hints for the episode Verify will contribute positively to the post-test scores is in accordance with the research outcomes. 4. Does the computer program improve students' problem-solving behaviour significantly? →The scores on the solution approach seem somewhat higher in the experimental group than in the control group. Students in the experimental group have improved as a result of using the computer program.
科技工具之特點	Causal analysis provided us with evidence that hints during different episodes differ in their effectiveness to improve problem solving. Use of hints that are connected to the solution approach (Plan) and feedback on the correct solution approach (Verify) were most effective. So, the program is most effective when students ask for help when planning a solution approach and when students inspect the correct answer after completing a problem. The reason for this may be that hints on a solution approach also entail information relevant to other episodes, providing students with a helicopter view on solving a specific problem.Students had the opportunity to select the type of hints that matched their preferred solution approach. Students who made frequent use of the available hints benefited from it. Most students used hints with informal solution approaches as well as hints with formal approaches.

編號:708

Data Extraction Form	
欄位名稱	內容
文獻來源	Erbas, A. K., & Yenmez, A. A. (2011). The effect of inquiry-based explorations in a dynamic geometry environment on sixth grade students' achievements in polygons. Computers & Education, 57(4), 2462-2475.
研究目的	The purpose of this study was to investigate the effects of using a dynamic geometry environment (DGE) together with inquiry-based explorations on the sixth grade students' achievements in polygons and congruency and similarity of polygons.
研究問題	1. What is the effect of using the Geometer's Sketchpad together with inquiry-based activities on the sixth grade student's acquisition and retention of achievement in and understanding of polygons and congruency and similarity of polygons compared to teaching with traditional direct instruction? 2. Do male and female sixth grade students differ on their acquisition and retention of achievement in and understanding of polygons and congruency and similarity of polygons? 3. Is there an interaction between gender and treatment regarding their acquisition and retention of achievement in and understanding of polygons and congruency and similarity of polygons? 4. To what extend do the computer-based activities contribute to students' better understanding of polygons and congruency and similarity of polygons, especially their prototypical thinking regarding polygons?
研究方法	The study was designed as a pre-test, post-test, delayed post-test experimental-control group study in which two different teaching and learning environments were utilized; one with traditional and the other with the incorporation of dynamic geometry activities. While the control groups were taught in the classrooms, the experimental groups learned the same topics through dynamic geometry activities at computers in the computer laboratory. The traditional instructional environment in the control group was merely based on the official mathematics textbook . The treatment in the experimental group included exploring and manipulating concepts related to polygons, regular polygons and their congruency and similarity. The teacher, students and computer activities (based on the Geometer's Sketchpad) interactions were available in dynamic geometry environment. The activities were prepared to allow student inquiry, while guiding and helping them to clarify relationships and make conjectures.
教學單元	□數與運算(Number & Operations) □代數(Algebra) ■幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	Polygons(四邊形)
教育階段	■國小 □國中 □高中 134 sixth grade students of a public elementary school
融入教學之工具	動態幾何軟體(Geometer's Sketchpad)
學習活動 (Learning activity)	教學策略：探索是學習(student-centered collaborative inquiry)
	1. The students in the experimental group were taught about the basics of Geometer's Sketchpad prior to the treatment by the researcher (the second author) for two class hours (i.e., 80 min). Two hours was sufficient as students were introduced basic computer skills in fourth and fifth grades. During the training, students engaged in activities involving constructing points and line segments, dragging the objects, measuring

	angles and distances, constructing perpendicular and parallel lines, constructing a circle and copying polygons and labeling objects in the Geometer's Sketchpad. 2. All of the instruction in the experimental groups took place in the computer lab. Students worked in pairs at the computers since there were only 20 computers arranged in a U-shape. The researchers designed 10 worksheets, which were adaptations of the inquiry-based activities in the textbook. In essence, worksheets used in the experimental group and the activities carried from the textbook in the control group had the very same learning objectives. The only difference was that the control group used hands-on materials like ruler and protractor while the experimental group worked with a dynamic geometry environment, the Geometer's Sketchpad, so that the students could discover the properties of geometrical shapes by measuring, exploring, manipulating, transforming and reaching to conclusions by themselves. While four of the worksheets required 20 min to complete, the rest required 40 min. While the first five worksheets were completed in the first week of the treatment, the rest was completed in the second week. In each lesson, the researcher (the second author) helped teacher to make a brief introduction to the new topic, especially taught certain properties of the Geometer's Sketchpad that they were going to use for the activities in worksheets. After this brief introduction, students were allowed to work on the computers by using the Geometer's Sketchpad with the assigned worksheet. As the students progressed through the worksheets, the researcher asked them to explain their actions and observations. The researcher offered technical assistance when a student had any difficulty with using the Geometer's Sketchpad. Also, as students worked through the worksheets the researcher prompted students periodically with comments such as "Think about what you are trying to do; Describe what you're observing and try to make generalizations; Think about how you might test your conjecture." When students finished working on each worksheet and wrote their findings and/or conclusions, a whole class discussion about the investigations and conclusions drawn was held. After the discussion, students were allowed to take additional notes and complete the worksheet if necessary. The same procedure was followed for all worksheets.
所收集之 研究資料	Pre-test、 post-test、and delayed post-test、videotaped classroom observations.
研究結果	Results of the study showed that the two-week long treatment created substantial improvement in students' achievement as compared to that in the control group, and the difference was significant in favor of the experimental group. Furthermore, the treatment had a significant effect on students' retention as measured by a delayed post-test conducted three months after the treatment was discontinued. In general, students in the experimental group showed great interest and motivation in learning geometry compared to those in the control group whom often showed lack of interest and curiosity 1. The results show students' performances significantly changed across times of testing (i.e., pre-test, post-test and delayed post-test), 2. There was a significant interaction effect between time of testing and groups.This indicates that student performance across time of testing was dependent upon the presence or absence of the treatment. Contrasts were performed comparing students' scores in experimental and control groups across the three time of testing. 3. Students in the experimental group were not spectators; all tried to participate and had insightful discussions with their pairs about the activities. 4. When the responses of experimental group students in the achievement

	test were analyzed in more detail, it was evident that the treatment helped them to think beyond prototypes 5. The students investigate the given situation and try to discover the associated structural properties. In doing so they actively collaborated and thought together as they made conjectures (e.g., opposite sides in a hexagon are parallel) and tested them through measuring and dragging. →it is evident that the students went beyond the ‘empirical’ level, where properties are ‘seen’ or ‘measured’ and exploited the theoretical control offered by the software.
科技工具之特點	1 the dynamic geometry environment allowed students to make connections between the figures and their properties through construction, measurement, and dragging. 2. the dynamic geometry environment encouraged students to make connections between the figure and structural properties associated with it while they are constructing them. 3. The Geometer's Sketchpad allowed students to play with the figures, construct dynamic and flexible geometric shapes by dragging and dropping. Also, the students created polygons and transformed them into irregular forms so that they could discover special cases of their original constructions. 4. The Geometer's Sketchpad has tools for flexible automaticity in calculating the measure of angles, sides, areas, and perimeters. Once computed, the measurements changed in real time as the angles, sides, areas, perimeters, or any other measurements calculated using these were stretched, shrunk or moved by the user. Affordances of such facilities with the Geometer's Sketchpad provided students with opportunities to make and test conjectures based on their observations. Furthermore, interactivity of the software allowed students to check various cases in a minimal amount of time. 5. The dynamic aspect of the software and inquiry-oriented structure of the accompanying lessons were clearly superior to printed materials. Unlike the students in the control group, students in the experimental group could alter, measure, move, stretch, and shrunk the figures constructed with the software and observe the resulting changes. Easiness and correctness of such actions were probably even more critical for students with coordination difficulties.

編號:712

Data Extraction Form	
欄位名稱	內容
文獻來源	Gürbüz, R., & Birgin, O. (2012). The effect of computer-assisted teaching on remedying misconceptions: The case of the subject "probability". Computers & Education, 58(3), 931-941.
研究目的	The aim of this study is to determine the effects of computer-assisted teaching (CAT) on remedying misconceptions students often have regarding some probability concepts in mathematics.
研究問題	
研究方法	The true-experimental research method, a pre- and post-test control group study was carried out with 37 seventh-grade students-18 in the experimental group (CAT) and 19 in the control group (traditional teaching). Participants were randomly assigned to two groups. In one of the groups, computer-assisted teaching (CAT) (experimental group: E) was performed, and in the other group, traditional instruction (control group: C) was conducted.
教學單元	□數與運算(Number & Operations) □代數(Algebra) □幾何(Geometry) □測量(Measurement) ■資料分析與機率(Data Analysis & Probability)
教學主題	probability
教育階段	■國小□國中 □高中 A total of 37 pupils studying at seventh-grade level in a primary school in the southeastern region of Turkey.
融入教學之工具	Computer-assisted teaching (CAT) material. (Two different materials were used in the context of this study. One of these was material consisting of animations and simulations prepared by using Macromedia Dreamweaver and Flash MX 2004 software. The other was material prepared using Java language and NetBeans editor.)
學習活動 (Learning activity)	教學策略:
	The implementations were carried out with students in experimental group. The students were requested to run the computer animations, and then they were asked to share their thoughts about probability with their friends. Moreover, the student groups asked such questions of each other as "Why are you doing that?" and "How did you get that" or made statements such as ".oh no, that is not right, because." and ". but that is wrong, because ." during the implementations. For this reason, the teacher refrained from responding to correct answers instead he asked some follow-up questions in a Socratic dialog fashion. During this process, instead of just lecturing, showing, giving tests, and evaluating, the teacher acted as an organizer, facilitator, counselor, cooperator, and supervisor. As a result, students became more active, improved their knowledge, questioned the knowledge they received, and were able to explain what they had just learned instead of behaving as merely passive receivers.
所收集之研究資料	Pretests、post-tests
研究結果	The findings can be summarized in the following way: CAT showed a positive impact on remedying students' misconceptions regarding the subject of probability and enabled conceptual learning. These positive effects are thought to be obtained by computer-assisted teaching materials accompanied by a student-centered learning environment.
科技工具之特點	It can be said that the intervention in the experimental group was more effective in remedying the misconceptions. Several factors are thought to be effective in this result: students construct their own knowledge in CAT

	environment, misconceptions regarding probability can be remedied by doing the exercises on the materials, the problems used in this process are taken from real life, and this process increases student motivation.

編號:732

Data Extraction Form	
欄位名稱	內容
文獻來源	Zurita, G., Nussbaum, M. (2004). Computer Supported Collaborative Learning Using Wirelessly Interconnected Handheld Computers. Computers & Education 42(3), 289–314.
研究目的	We describe how weaknesses in coordination, communication, organization of materials, negotiation, interactivity and lack of mobility can be solved with a mobile computer supported collaborative learning environment with Handhelds interconnected by a wireless network.
研究問題	
研究方法	In order to understand children's social interactions and shared learning of face-to-face CL environments better, first we exhaustively observed children working with two (math and language) collaborative activities without technological support. Our approach was to watch the videotapes repeatedly, with the focus on how the groups behaved during the key issues. To find weaknesses in: (a) Coordination of the group members, (b) communication between members, (c) organization of the material by the members, (d) establishing of negotiation' instances of the members, (e) interaction realized by members, and (f) changes in the members' physical mobility. ＊CL(Collaborative learning) activities 與 Mobile Computer Supported Collaborative Learning (MCSCL) activities 做比較
教學單元	■數與運算(Number & Operations) □代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	Addition and subtraction operations.
教育階段	■國小□國中 □高中 48 students elementary school.
融入教學之工具	行動載具(Mobile Computer Handheld)
學習活動 (Learning activity)	教學策略: Collaborative learning、Mobile Computer Supported Collaborative Learning
	The aim is that children work collaboratively on an educational objective, through the use of their interaction, communication and negotiation skills, with Handheld support(分成小組進行學習活動). For the math MCSCL activity, groups are made of three and five members, the activity consists on each group member having a set of given objects and achieving the specified number for each of the objects by sending and receiving these from another member of the group. The child has one orange, three bananas and two apples shown in the central (blue) box, and has to reach two oranges, four banana and three apples shown in the upper part of central (blue) box. Each member is identified by a given color, used as the main background. The others members are identified by the colors of the buttons on the bottom section of the display. The child selects the button that corresponds to the group member from whom she or he wants to receive an object . The child who sends the object first selects it from the object windows in the screen center, and then chooses to which member she or he wants to send it, pressing the button of the corresponding color. This button will be available for the child who wants to send an object, only if the other child previously selected the receiving button from the corresponding color. For example, purple, when wanting to receive an apple, should specify from whom wants to receive it, the red one for instance. To perform this action, she or he should choose to press their red button at the lower end of the display.

	Then red will choose the apple to give, and only with purples acknowledge to receive. Only then, the give button activates itself to perform the giving. After choosing the purple button, the quantity of red's apples is decreased while the quantity of purple's apples is increased, and the state changes to be able to choose new members from whom to receive an object. On the contrary, if red wants to give an object, then she o he should mark the object so that their state changes with the colored buttons of members who want to receive the object. It is possible that some members reach their individual goal while others have not. The fact also shown to the member with purple and green color, using a red icon with a star in the upper part of the display. Only when all members reach their goal, the three buttons in the bottom section of the display appears to all of them, since the aim is the global object, and not the particular one.
所收集之 研究資料	Quantitative and qualitative data was gathered from video, field notes and interviews. The observations and interviews were targeted to analyze the children's behavior and the users' behavior towards other children and towards the machine.
研究結果	For the math MCSCL activity, this shows that the Handhelds are tools that facilitate coordination of a greater number of members transparently, apart from transparently supporting mobility to the members who need it. In a collaborative activity without technological support, the transaction is guaranteed by a rigid dependence to the roles and rules. These are frequently not obeyed by all the members, especially when children are present. The comparisons showed that in both cases there was as statistical significant difference with an alpha level of 0.05 between score means of the tests. Therefore students did improve their knowledge of math and language with the MCSCL activities 1. Interactivity. To assure interactivity between participants, in the language activity each member has an object that they require to construct the common aim, i.e., a syllable. This information must be shared with the other members to form the words. This forces members to interact with their partners, avoiding other members to take control. In the math activity, the teacher determines the number of objects each of them initially has and to which they have to reach, which forces the interaction among specific members. In both MCSCL activities, the members of the group can take the technology with them, which encourages face-to-face social interactions. The anytime-anywhere characteristic of Handhelds supports interactivity between members, when working on MCSCL activities. 2. Mobility. The mobile network facilitates face-to-face work and the capacity to freely move while the members take their records with them, which allowed the members to displace naturally. This favors the mobility of the members of the group while working with the group partners, in both MCSCL activities.
科技工具之特點	1. The MCSCL activities support transparently the collaborative work by strengthening the: (a) organization of the managed material; (b) social negotiation space of group members; (c) communication among the group members, through the wireless network that supports the social face-to-face network; (d) coordination between the activity states; (e) possibility to mediate the interactivity; (f) encouraging of the members' mobility. The last two make a difference in how collaboration is supported between MCSCL and CSCL activities, due to the use of Handhelds that offer a manageable solution for the coordination, communication and interactivity, which is possible on PC's, plus the

	participants' mobility. 2. MCSCL activities manage and encourage tasks that include: (a) organization of information, (b) enabling students to collaborate in groups, (c) monitoring real-time progress with respect to learning objectives and (d) controlling the interaction, negotiation, coordination and communication. Handheld computers are emerging as a flexible and portable solution that provides students with ''at hand'' support to engage in collaborative activities anytime, anywhere.

編號:733

Data Extraction Form	
欄位名稱	內容
文獻來源	Chang, K. E., Sung, Y. T., & Lin, S. F. (2006). Computer-assisted learning for mathematical problem solving. Computers & Education, 46(2), 140-151.
研究目的	The purpose of this paper is to propose a new system (named MathCAL) that is based on the four problem-solving stages mentioned: (1) understanding the problem (2) making a plan (3) executing the plan (4) reviewing the solution. The system assists in achieving a successful outcome at each stage. The proposed system was evaluated by conducting an experiment using fifth-grade students in elementary school as subjects. The following two issues are explored here: (1) Comparing problem-solving ability before and after the experiment. (2) Whether assistance provided at various stages helped students with their problem solving.
研究問題	
研究方法	This study used a two-way mixed design. The between-group independent variable was group (or treatment), dichotomized into ‘‘not using the computer-assisted problem-solving system’’ (control group) and ‘‘using the computer-assisted problem-solving system’’ (experimental group). Participants are randomly assigned to two groups. The within-group independent variable is test, dichotomized into pre- and post-tests. The dependent variable was student scores in mathematical problem-solving pre- and post-tests.
教學單元	■數與運算(Number & Operations) □代數(Algebra) □幾何(Geometry) ■測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	This experiment used a fifth-grade mathematics textbook, from which we selected problems from six units, namely 「the addition and subtraction of real fractions」、「the multiplication of fractions」、「pi, sectors and capacity」、「the area of triangles」、「unit cost and vertical planes」、「the area of a trapezium」.
教育階段	■國小□國中 □高中 49 fifth-grade students selected from four classes in an elementary school in Taipei
融入教學之工具	Computer-assisted system named MathCAL (This system uses the schema representation to visualize concepts in the problems).
學習活動 (Learning activity)	教學策略: The experiment spanned 6 weeks, with one pretest, one post-test and eight problem-solving practice sessions (twice a week, 40 min each). One week before the formal experiment began, we gave the pretest to the students in the experimental and control groups (50 min) to test their mathematical problem-solving abilities, after which the formal experiment was performed. The students in the experimental group practiced using MathCAL, and the control group of students solved 10 mathematical problems on paper in each session. At week 6 the students in the experimental and control groups were given the 50-min post-test.
所收集之研究資料	Pretest and post-test

研究結果	The results showed MathCAL to be effective in improving the performance of students with lower problem solving ability. This evaluation allowed us to address the problem of whether the assistances in various stages help students with their problem solving. These assistances improve students problem-solving skills in each stage. ＊Analysis of learning results 1. the pre- and post-test scores in the experimental and control groups. 2. the problem-solving ability in the experimental group was significantly better than that in the control group. ＊Analysis of problem-solving stages 1. Number of problems practiced. On average the students in the experimental group completed 38.4 of the 80 problems compiled for this experiment. We discovered that the highest number of problems completed was 62, while the lowest was 8. 2. Average number of steps for each problem. In the "making a plan" stage the system provides some built-in problem-solving steps for each problem, from which the students can select the ones that may help in solving the problem. Table 3 shows that the number of steps used by the students for each problem (2.5) and the number of steps in the correct answer (2.2) were very similar. 3. Highlighting. Table 3 shows that the proportion of students who highlighted important information was quite low (16.7%). In 63% of cases this was the entire information, and in 37% of cases this was numbers or phrasal information. In other words, most cases involved highlighting in its entirety, which is no better than not highlighting. The highlighted content showed that some of the students used highlighting to help them identify the relevant information in the problems 4. Use of calculators. Table 3 shows that only 8% of the students used calculators during their problem solving 5. Referring to correct answers. Table 3 shows that 46% and 50% of the students referred to the correct answers in the "making a plan" and "executing the plan" stages, respectively. Although the students solved nearly half of the problems by referring to the system's built-in answers, the significant difference between the problem-solving abilities in the experimental and control groups suggests that self-initiated learning took place while students were engaged in the process of referring to the answers. 6. Constructing the solution tree. Table 3 shows that only 42% of the students constructed complete solution trees, whereas we had expected that all of the students would review the problem- solving procedures for each problem through the solution trees after they had completed the "executing the plan" stage. ＊The effectiveness in improving students problem-solving ability →The empirical results showed that even though the experimental group practiced with about half as many problems as the control group, the intervention of a computer-assisted problem-solving system improved students problem-solving ability. ＊The effects of providing assistance at the various stages of the problem-solving procedur. →A computer-assisted problem-solving system designed in stages can provide two advantages: (1) Decreasing the cognitive load and frustration in learning through the system's guidance and feedback. (2) Improving students problem-solving skills by using a step-by-step approach.
科技工具之特點	1. Understanding the problem：the system provides a "drawing pen" function for the student to highlight important information in the problem.

	2. Making a plan：The main function in this stage is providing the student with some built-in possible steps for solving the problem, from which the student selects the most appropriate one. 3. Executing the plan ： the system provides three frames. Each of the problem-solving steps in the plan generated from the ‘‘making a plan’’ stage is listed in the ‘‘planning frame’’ in the form of a ‘‘solution step’’ button. In the ‘‘planning frame’’, there are two ‘‘solution step’’ buttons. Whenever a student clicks a button, the system displays an empty schema in the execution frame, in which the student may enter related operands and an operator into the appropriate nodes. To fill in the operand, the cursor is moved over the position of the label attribute of the operand node in the schema. Right-clicking the mouse reveals a list of labels, one of which is selected and the student fills in a number for the value attribute. The operator is determined by using the ‘‘operator buttons’’ to input values into the operator node. After filling in the operands and operator, the student has to fill in the label attribute of the result node, and then the value of the result is calculated automatically by the system and displayed in the result node.After finishing schemas corresponding to all ‘‘solution step’’ buttons, the system combines the schemas in the execution frame to form a solution tree 4. Reviewing the solution：In this stage the student fills in the expressions and answers. After filling in the blanks in the expression in the ‘‘evaluation frame’’, the student presses the OK button which triggers the system to evaluate the results, and messages appear that indicate whether any mistake was made. Also, the student may press the ‘‘demo’’ button to see the correct problem-solving steps.

編號:734

Data Extraction Form	
欄位名稱	內容
文獻來源	Chang,K. E., Wu, L. J., Weng, S. E. & Sung, Y. T. (2012). Embedding game-based problem-solving phase into problem-posing system for mathematics learning. Computers & Education 58(2), 775-786.
研究目的	The purpose of the study is to understand the effect of the system on the problem-posing and problem-solving abilities and flow experiences of elementary students. This study proposed a system with four problem-posing phases: posing problem, planning, solving problem, and looking back, in which the " solving problem" phase is implemented by game-scenarios to support students in the process of problem-posing, allowing them to fully engage in the problem-posing activities. The study also investigated the effect of the problem-posing system on students' problem posing ability, problem-solving ability, and flow experience by examining the processes of problem-posing system.
研究問題	
研究方法	This research we implemented a quasi-experimental design. The independent variable was the group treatment (that is, the problem-posing system vs. the traditional paper-based instruction), and the dependent variables were the posttest scores for the four dimensions of problem-posing and on overall problem-solving ability.
教學單元	■數與運算(Number & Operations) □代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	The topic used for research was the addition and subtraction of fractions with different denominators, presented in the form of word problems.
教育階段	■國小 □國中 □高中 Four fifth grade classes from an elementary school in Taipei, with 92 participants.
融入教學之工具	A problem-posing system: Four phases including posing problem, planning, solving problem, and looking back, in which the "solving problem" phase is implemented by game-scenarios. The system supports elementary students in the process of problem-posing, allowing them to fully engage in mathematical activities.
學習活動 (Learning activity)	教學策略:
	＊The experimental group： used the problem-posing system; The control group followed the traditional paper-based approach. ＊Instructions are provided at each interface to help students understand the process of problem-posing. When they log into the system and enter the interface of the problem-posing activity, they encounter four further phases. 1. Posing problems. Students are asked to pose problems in a given range and type them into the system. They type in the content of their problems and the correct answers. 2. Planning. After students send out the posed problems, they proceed to the interface in which the posed problems are verified. All the posed problems are listed, and students can refine them as they wish. By clicking on the trial button, students can try out the questions they have created in the game-based setting. They obtain feedback from their teacher and judge whether the solution is reasonable. They can use the refine button to refine their posed problems. 3. Solving problem. In this phase, students solve the posed problems in the game-based setting. The posed problems and their detailed response

	options are shown on the left of the interface. The game field is displayed on the right of the interface, with response options embedded into it. The system contains six interactive games: Coby the Cat, Millionaire, StarWars, Rescuing the Mice, Uncle Tu Climbingthe Coconut Palm, and Racers. 4. Looking back. After students complete the phase of solving problem, they are taken to the feedback interface, which provides immediate information about their performance, such as the time spent, the number of correct answers, and the scores on the phase of solving problem. After the entire phase of solving problem is completed, students get feedback from their teacher. Finally, students return to the phase of posing problem and start generating a new problem. ＊The experimental classes: Were given an additional 40 min to try out the system on their own. Next, the experimental classes posed problems using the system for 20 min, and verified these self-posed problems for another 20 min. Students got feedback from their teacher and were given 10 min to refine their self-posed problems. They were then asked to put their revised posed problems into the system again. In the following 20 min, students were asked to solve posed problem in the game-based setting. Finally, students obtained feedback from the teacher and were given new ideas to create new problems for 10 min. The control classes ：were involved in the same problem-posing activity by using the traditional paper-based method. Students in control group first carried out the paper-based problem-posing activity for 20 min. Then, they were asked to verify their self-posed problems for 20 min and revise the questions for another 10 min. For the next 20 min they solved the posed problems using paper and pencil. Finally, they received feedback from the teacher, and over the next 10 min generated new questions.
所收集之 研究資料	Pre- and posttests for problem-posing、Pre- and posttests for problem-solving、The Flow Experience Scale.
研究結果	The results revealed more flow experiences, and higher problem-solving and problem-posing abilities in the experimental group. 1. Analysis of problem-solving scores: The posttest performance of the experimental group was better than that of the control group. The experimental group was found to be more effective than the control group. In other words, students with lower pretest scores benefited more from the problem-posing system. 2. Analysis of problem-posing scores: The overall scores of problem-posing, accuracy, flexibility, elaboration, and originality were significantly higher in the experimental group than in the control group. 3. Analysis of the Flow Experience Scale: Indicated that the flow experience score was significantly higher in the experimental group than in the control groups. ＊Three conclusions 1. The overall scores of problem-posing, accuracy, flexibility, elaboration, and originality were significantly higher in the experimental group than in the control group. 2. The results of the Flow Experience Scale indicate that the score of flow experience was significantly higher in the experimental group than in the control groups. 3. The problem-posing system was effective at promoting students with lower problem-solving scores
科技工具之特點	1. The scenarios in the system might provide students with more opportunities to reflect on their problem-posing techniques by examining posed problems. The features of the system allowed students to improve

	their problem-posing skills. Students in the experimental group repeatedly returned to the interface of solving problem to improve their scores. Once they did so, they had more opportunity to view more posed problems and solve them. Through system function, comments and feedback given by the teacher, the student can refine his or her problem-posing skill. Thus, students in experimental group performed better in the problem-posing posttest. 2. The motivation of the experimental group might be enhanced by the system so as to improve their problem-solving ability. Immediate feedback and reward characteristics from games (for example, the game scores and rankings) will encourage students to complete the problem-solving tasks.

編號:769

Data Extraction Form	
欄位名稱	內容
文獻來源	Graham*, T., & Smith, P. (2004). An investigation into the use of graphics calculators with pupils in Key Stage 2. International Journal of Mathematical Education in Science and Technology, 35(2), 227-237.
研究目的	The purpose of this study was to look at how pupils would react to the use of graphics calculators, particularly the use of a simple program, in Key Stage 2 mathematics lessons within the framework of the National Numeracy Strategy.
研究問題	
研究方法	This paper outlines an experiment in which pupils in Key Stage 2 were encouraged to use graphics calculators, in particular two simple programs, which helped them develop recall of their tables and allowed them to practice multiplication.
教學單元	■數與運算(Number & Operations) □代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	Multiplication.
教育階段	■國小 □國中 □高中 A Year 5 class of pupils
融入教學之工具	Graphics calculators
學習活動 (Learning activity)	教學策略:
	The children were given some initial exposure to the calculators to familiarize them with the layout of the calculator and to allow them to practise the necessary keying skills. They picked this up very quickly; the concept of menus didn't pose any particular problems. They seemed to follow instructions well, although on occasions some children rushed ahead and ran into problems. They normally only did this once, the next time choosing to follow instructions carefully and to follow the teacher, who was working on the large screen. During these initial introductory sessions the children worked mainly with the tables program. They also used a game called 'The Weakest Link', in which the calculator was used simply as a generator of tables questions—the children had to answer quickly and accurately. They enjoyed this enormously. The calculator allowed for differentiation and enabled able and less able children to compete. This and similar activities meant that the calculators soon became a familiar tool around the classroom. The children also had individual access to the calculators, working sometimes alone or other times in pairs. They even started playing their own games of 'weakest link'. Once the pupils were familiar with the calculators, the teacher introduced regular calculator use. The calculators were used in the classroom for three consecutive weeks. They were used during the dedicated daily mathematics lesson, most commonly during the mental oral part of the lesson. They were occasionally used during the main part of the lesson and plenary. The children also had open access to the calculators during registration times, where they could run programs linked to the above key objective. ＊The ways in which the graphics calculators were used are summarized below： 1.Demonstration tool – in conjunction with a palette and OHP, probably used with the whole class. 2. Mini computer – using programs that the pupils access on an individual basis, while working individually. 3. Functional tool – for doing arithmetic, creating tables of values, etc. in

	order to investigate some aspect of mathematics.
所收集之 研究資料	Questionnaire、free answer question、Targets relating to performance on the times tables.
研究結果	＊Questionnaire These were all positive statements about the use of the calculator that reflected the pupils' enjoyment, interest and enthusiasm for using the graphics calculators. They also expressed a strong feeling that the use of the graphics calculator had helped to improve their understanding of mathematics. ＊Free answer question The majority of the pupils in the class felt that the graphics calculator did help them to learn mathematics. That reflect the same sort of enjoyment and improved understanding that were expressed in the responses to the statements.
科技工具之特點	The instant feedback given by the calculator may have had a positive effect on the pupils learning.

編號:980

欄位名稱	內容
文獻來源	Lin, C., Shao, Y., Wong, L., Li, Y., & Niramitranon, J. (2011). The impact of using synchronous collaborative virtual tangram in children's geometric. Turkish Online Journal of Educational Technology, 10(2), 250-258.
研究目的	This research was to investigate whether the students can develop mathematics concepts through playing the Tangram puzzle collaboratively, and solving problems together through discussion
研究問題	
研究方法	Students were first divided into eight groups of high-, medium- and low-ability according to the pre-test scores. There were 3 students in each of those seven groups and 4 students in the last group. The eight consist of two high-ability groups (Group 1 and Group 2), two medium-ability groups (Group 3 and Group 4), two low ability groups (Group 5 and Group 6), and two mixed groups with high-, medium- and low-ability students (Group 7 and Group 8).
教學單元	□數與運算(Number & Operations) □代數(Algebra) ■幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	Puzzle- shape solving
教育階段	■國小 □國中 □高中 25 Grade 6 (11-year-old) students in an elementary school
融入教學之工具	Group Scribbles (virtual Tangram puzzle) 1.Group Scribbles (GS2.0), a computer-supported collaborative learning system developed by SRI International, was adopted to conduct small group collaborative for their puzzle- shape solving. 2. The interface of Group Scribbles contains three main parts: public board, group board and private board. The teacher can add, move and adjust the boards to his/her needs. The virtual Tangram puzzle was added to the toolkits. Each piece of the Tangram puzzle had numbers on it and can be rotated and moved freely.
學習活動 (Learning activity)	教學策略:合作式學習
	1. Group Scribbles warm-up practice (30 minutes): The teacher introduced to the students the electronic notes, theshared space and the concept mapping tool to familiarize them with the GS environment. The students then practiced to make a square with the Tangram puzzle set by rotating and moving each piece of the Tangram puzzlefreely. 2. Perform the task 1 (40 minutes):Sudents in each group were required to make a funnel within 8 minutes. The results of each group were shared in the class and the teacher made some interpretation. During the classes, the teacher monitored the activities of all the groups and provided assistance where necessary. 3. Perform the task 2 (40 minutes):All groups practiced piecing up a sailing boat. Again 8 groups had a competition to complete a ‘sailing boat’ collaboratively within 8 minutes. Results were shared and peer assessment took place.
所收集之研究資料	Pre-test、Post-test、questionnaire、Student interviews、videos。
研究結果	The results suggest that children’s competency in rotation and space of shapes had been improved and the scores gap between lower and higher achievers had been narrowed. Such a collaborative Chinese Tangram activity may facilitate peer negotiation, enhance children’s belief toward problem solving, and benefit each child to share resources, and a positive interdependent learning context can naturally be developed.

1. Patterns found in the process of collaborative tangram playing During the process of this experiment, five patterns were found out from analysis of field notes and video recordings.

(1) Communication in the group: It was identified that the students had carried out a mixture of GS-based and face-to face communications. Two people sitting next to each other often turned aside to watch one screen together when they had discussion. The third participant sitting opposite to those two, moved him/herself to the other side to view the same screen.

→This indicates all group members were engaged in the discussion. They carried out face-to-face discussion as well as online communications.

(2) Ways of collaboration: When a member in the group had difficulties in handling the Tangram puzzle on his/her computer, other members would move themselves to give help and make demonstration. Such behaviors helped to establish the sense of positive interdependence and sharing of failure and success, thus improving the collaboration. Gesticulating on the screen could be regarded as the replacement of actual pieces grabbling in traditional tangram. Within a group this physical behavior could be a great aid for verbal discussion.

(3) Sharing the achievement: One delegate of each group was asked to interpret their patterns of puzzle shaping and present the achievements of the group. each group's work. Students may find out other patterns of composition constructed by other groups on the public board of GS.

→By showing all groups' results on the public board through projecting all students can discuss the work within the whole class, improving their individual knowledge through the collective knowledge.

(4) Discussion: The teacher explained the concept of poly forms, the same size in different shapes. The reflection of their problem-solving process would increase students' understanding to the Tangram puzzle. In addition, the teacher interpreted the area concept of square, parallelogram and quadrilateral. the teacher could demonstrate the concept of area by both manipulating the virtual Tangram puzzle as well as drawing shapes on the board. The teacher found it easy to summarize and explain the geometrical concept based on students' own collective cognition and knowledge.

(5) Peer group assessment: After Task 2, all students in the class did a peer assessment to other groups with 'sheet' and "stamp" in GS in the scale of 1 to 5. The result of their peer assessment . Each group could easily obtain peer feedback in this way. That may encourage students to make rigorous observation which will lead to critical thinking.

2. Findings from the post-questionnaire.

(1) Usability: The mean of Question 1 and Question 2 are 2.84 and 3.48 respectively. Only 12% of the students were not familiar with the touch pen and it took time for them to get used to. During the post-interviews that followed, the students complained that their peers in other group move their Tangram puzzle in the process. We should consider it as a point to improve the system.

(2) Strategy in problem solving: All students had applied different strategies such as problematical thinking, trial and error, and peer help searching to achieve their goal except differed in ways of discussion.

(3) Engagement: Students were very engaged in puzzle piecing and could help each other. More than 80% of the students held positive view to collaborative puzzle shaping and struggled for the goal.

(4) Learning activities: Some groups lacked collaborative skills which had resulted in conflicts. 20% of the students felt being isolated or not being able to communicate with their group mates whenever a particular group member started dominating the group. However, 76% of the

	participants believed that playing virtual Tangram would stimulate more idea exchange and interaction with their group mates. In general, over 70% of students could complete the puzzle shapes and enhance their understanding of geometric graphics. Over 90% of the students could reach the goal through collaboration despite that 12% of them were less actively engaged in the activities and held negative views. (5) Motivation and interest: More than 70% of the participants stated that they liked to work with their group mates to solve problems. Over 80% of them anticipated alternative challenge of puzzle shaping and expected more interesting collaborative activities like that. This indicates their strong willingness of learning through playing the tangram and consequently they were fully motivated to learn. 3. Findings from the interviews. (1)Impact of collaboration in problem solving: The group strategy to ask children to challenge jigsaw puzzle as a group demonstrated that in the cooperative process of discussion and sharing students also created and exchanged ideas, had their group work skills improved through interaction, thereby had promoted the motivation and interest of learning (2) Learning experience: Playing Tangram puzzle collaboratively allows students to obtain empirical experiences. Students held positive views to the cooperative Tangram puzzle. They claimed that they could play puzzle with group members easily and which is more interesting than individuals. But some of the students had difficulty to use the touch pen, which get in the way to organize and compose the shape freely. (3) Learning Gains: By rotating and moving each piece of the Tangram puzzle, it helps students to understand the geometry and size composition. Not only can review students' previous mathematics knowledge but also stimulate their imagination.
科技工具之特點	1. The collaborative virtual learning tool enabled resource sharing and formed the interdependent learning environment. 2. The collaborative puzzle shaping with the Tangram puzzle can enhance the shapes rotation and spatial ability. Furthermore, the students' competency in spatial reasoning and sensing had also been improved.

編號:983

Data Extraction Form	
欄位名稱	內容
文獻來源	Nguyen, D. M., & Hsieh, Y. C., Allen, G. D. (2006, 06). The Impact of the Web-Based Assessment and Practice on Students' Mathematics Learning Attitudes. Journal of Computers in Mathematics and Science Teaching 25 (3), 251-279.
研究目的	This study investigates the effects of web-based assessment and practice on improving middle school students' mathematics learning attitudes. The research mainly investigated: 1. The effect of web-based assessment and practice on middle graders mathematics learning attitudes. 2. The mathematics learning attitudes among students in the web-based group in terms of genders and different ethnicities.
研究問題	
研究方法	Quasi-experimental design and combinations of quantitative and qualitative data collection and analyses.
教學單元	■數與運算(Number & Operations) □代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	Four online homework and practice sets were designed for this study. These sets included practice tasks on fractions and decimals with randomized items, automatic grading, and immediate adapted feedback.
教育階段	□國小 ■國中 □高中 Participants were 74 seventh graders, 44 males and 30 females, from a middle school in the Southern Texas.
融入教學之工具	The web-based assessment and practice (WP)
學習活動 (Learning activity)	教學策略:
	Students in the web-based group (the WP group) worked with online practice tasks in their school computer lab during the math class periods. Students in the paper-and-pencil group (the TP group) worked with the conventional paper-and-pencil practice tasks in the traditional classroom with their mathematics teacher. Students participated in this study 30 minutes each day and three times a week. The study lasted for three weeks. Prior to the study, all students were asked to complete the presurvey. During the study, both WP and TP groups practiced four different sets of homework as described in the homework and practice tasks section. The WP group practiced the homework in the computer lab. They had an option to check if they got the correct or incorrect answer for each question. They also received immediate feedback for each incorrect answer and the total score when they finished each homework set. Because of the random feature, students were allowed to practice as many times as they wished. These students were informed that the highest practice score would be recorded and reported to the teacher. Every time students repeated each homework set, the homework items were slightly changed by the random parameters, such as numbers, words, or choices, but the mathematics content and concept remained the same. The TP group practiced the same homework sets as the WP group, but on printed worksheets. There were two alternative versions of each printed homework task available. Students in the TP group were encouraged (but not required) to take these alternative ones for extra practice. If students had questions, they could get help from their teacher. The students' homework papers were collected, manually graded, and returned to students by their teacher. At the end of the study, the WP and TP groups

	both took the mathematics postsurvey.
所收集之 研究資料	Survey questionnaires (pre-and-post-surveys)、Interviews.
研究結果	The results of the study indicate that with the opportunities of drilling and practicing on the computer and receiving instant scores and adapted feedback, students had gained interests in doing mathematics, and formed a perception that they became smarter in problem-solving. ＊Students' Attitude Toward Mathematics Learning and Web-Based Assessment: The descriptive analysis and the interview results indicated that the WP students were generally enthusiastic about their web-based learning experience. Many of WP students reported that they enjoyed working with computer assessment, and preferred to have more computer math practice. ＊Comparisons Between the Web-Based and Paper-and-Pencil Drill and Practice: It was shown that a majority of participants either agreed or strongly agreed that they enjoyed doing work on the computer and they preferred to have more lessons on the computer. The interview notes indicated that students perceived lessons and assignments on the computer to be clearer to read, and that the mathematics problems on the computer appeared to be easier than on printed papers. Students also enjoyed the computer affordability; that is, easy to type and easy to erase. Students enthusiastically expressed that they felt smarter while doing mathematics on the computer, and gained more confidence once provided with opportunities for multiple practices and receiving immediate feedback for improvement. These effects reached beyond what paper-and-pencil could do for all students.
科技工具之特點	1. The immediate feedback and instant scoring appeared to be the most attractive features of the web-based learning. These features might also affect the students' success or failure in mathematics learning. This finding reinforced the presumption that students highly desire confirmation of their understanding and knowing their performance. Students need to recognize their mistakes as early as possible, so that they can have the chance to correct and adjust their understanding before they start to forget how they made those mistakes. The immediate feedback, even though for some particular questions, only telling students whether their answer is correct or incorrect, is of importance to let students recognize their misunderstandings and identify the learning areas that needed to spend more time and effort for improvement. The feature of web-based practice to mitigate anxiety, and the web-based immediate scoring for helping their understanding and performance. That led students to have more control over their work and their effort. Additional information from the survey questionnaire and interview results also demonstrated that web-based assessment with features of immediate feedback, clear instruction, and instant scoring gave students better guidance to direct their learning. 2. Web-based assessment and practice offered students multiple practice opportunities that eventually encouraged students to spend more time on tasks and attain higher levels of achievement. The feature of the randomized item generation provided by the web-based assessment system offered students multiple versions of each homework set. Students could practice as many versions or as many times as possible when it is necessary. Along with the immediate feedback and automated scoring, the automatic item generation encouraged students (a) who highly desire a perfect performance, having an opportunity to reach the maximum scores, and (b) who are not confident with their understanding,

	confirming and reconfirming the mathematical concepts and procedures.

編號:1189

Data Extraction Form	
欄位名稱	內容
文獻來源	Doerr, H. M., & Zangor, R. (2000). Creating meaning for and with the graphing calculator. Educational Studies in Mathematics, 41(2), 143-163.
研究目的	In this study, we seek to describe how one teacher's knowledge and beliefs about the graphing calculator were reflected in her pedagogical strategies. We then describe how these strategies led to the co-construction, with the learners, of a particular set of ways in which the graphing calculator became a tool for mathematical learning. We closely examine how the students opted to use the graphing calculator to support their mathematical learning throughout their year-long pre-calculus course Lastly, we discuss our findings on how the graphing calculator, as with any tool or technology, enabled and constrained both pedagogical practices and student learning.
研究問題	
研究方法	In this paper, we report the results of a qualitative, classroom-based study that examined (1) The role, knowledge and beliefs of a pre-calculus teacher. (2) How students used graphing calculators in support of their learning of mathematics. (3) The relationship and interactions between the teacher's role, knowledge and beliefs and the students' use of the graphing calculator in learning mathematics. (4) some limitations and constraints of the graphing calculator technology that emerged within the classroom practice.
教學單元	□數與運算(Number & Operations) ■代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	Pre-calculus curriculum : The classes were observed over three units of study on linear functions, exponential functions and trigonometric functions.
教育階段	□國小 □國中 ■高中 The classes were taught by the same teacher and each met for five sessions for a total of 270 minutes per week. One class had 17 students and the other 14 students, all between 15 and 17 years of age.
融入教學之工具	Graphing calculator: TI-82 or TI-83 graphing calculators.
學習活動 (Learning activity)	教學策略: All of the students had either TI-82 or TI-83 graphing calculators. These devices are rich in graphing and statistical functionality, although lacking in symbolic algebra capability. The classroom was equipped with a computer, printer and a 'graph link cable' that could be used to transfer pictures of the calculator graph to the computer for printing. The link cable also could be used to transfer data and programs between the computer and calculator, but this feature was rarely used. On the other hand, students readily transferred data and programs between calculators using the calculator-to calculator link cable. The classroom was equipped with a view screen that allowed the calculator screen (but not the keystrokes) to be projected using a standard overhead projection unit. Classroom instructional activities regularly alternated between modeling problems investigated by the students within a small group and whole class discussion for sharing progress, discussing solution methods and extending results. The instructional tasks were designed so that the students would create quantitative systems which describe and explain the patterns and structures in an experienced situation and which can be

	used to make predictions about the situation. The students were asked to interpret data, to find meaningful representations of the data (typically tables, graphs and equations), and to generalize relationships beyond the particular situation at hand. The concept of the rate of change of a function and the transformations of exponential and trigonometric functions were addressed throughout the problem situations.
所收集之 研究資料	All class sessions were observed by two or more members of the research team. Extensive field notes, transcriptions of audio-taped group work, transcriptions of video-taped whole class discussion, and interviews and planning sessions with the teacher constituted the data corpus for this study.
研究結果	The results of this study suggest that the role, knowledge and beliefs of the teacher influenced the emergence of such rich usage of the graphing calculator. The teacher's role in encouraging interpretation and explanation led to a valuing of meaningful mathematical constructions for equations, to the transformation of rate from a computational task to an interpretive task, to the valuing of algebraic arguments to support graphically and numerically generated conjectures, and to a de-valuing of regression equations or appeals to the calculator as an authority in a mathematical argument. We found that the calculator as a private device inhibited mathematical communication in a small group setting, while the shared screen of the graphing calculator appeared to be a powerful tool for supporting the comparison and unification of mathematical ideas. ＊Five categories of patterns and modes of calculator use by the students. The focus of our analysis is on how and why these features were used in the problem contexts and instructional situations. The graphing calculator can in certain situations take on more than one role simultaneously. 1. The calculator as a computational tool: Evaluating numerical expressions, estimating and rounding. 2. The calculator as a transformational tool: Changing the nature of the task. 3. The calculator as a data collection and analysis tool: Gathering data, controlling phenomena, finding patterns. 4. The calculator as a visualizing tool: Finding symbolic functions, displaying data, interpreting data, solving equations 5. The calculator as a checking tool: Confirming conjectures, understanding multiple symbolic forms
科技工具之特點	1. The graphing calculator and the attached pressure belt became a tool that supported the students in controlling the data collection through cycles of interpretation of the graphical results and purposeful changes to the physical phenomena of breathing. 2. The graphing calculator provided a visual representation of the continuous function that described the rate of change in the vertical motion of the Ferris Wheel. This became the link between the discrete data table, which was missing a critical data point (the maximum value), and the physical phenomena, which, from their experience with the wheel, the students conjectured must reach some unique maximum value. →The graphing calculator's use as a visualizing tool was also reflected in how the students solved equations or inequalities. This visual approach seemed to support their description of the amount of money in the bank reaching a given value. 3. Students were free to use their calculators as they wanted and were actively encouraged to use them to calculate, explore, confirm, or check mathematical ideas.

編號:1228

Data Extraction Form	
欄位名稱	內容
文獻來源	Marrades, R., & Gutiérrez, Á. (2000). Proofs produced by secondary school students learning geometry in a dynamic computer environment. Educational studies in mathematics, 44(1-2), 87-125.
研究目的	The main objective of the study was to investigate how DGS environments can help students improve their conception of proof in mathematics and their methods of justification.
研究問題	A hypothesis of this study is that the Cabri environment we have designed is more helpful than an environment based on non-computer didactical tools or on the traditional blackboard and-textbook, because the Cabri environment favours classroom organization to promote active methodologies. Another hypothesis of our study is that the Cabri environment we have designed does not impede the improvement of students' justification skills.
研究方法	We employ this framework to investigate ways in which dynamic geometry software can be used to improve students' understanding of the nature of mathematical proof and to improve their proof skills. We present the results of two case studies where secondary school students worked with Cabri-Géomètre to solve geometry problems structured in a teaching unit. The teaching unit had the aims of: i) Teaching geometric concepts and properties, and ii) helping students to improve their conception of the nature of mathematical proof and to improve their proof skills. By applying the framework defined here, we analyze students' answers to proof problems, observe the types of justifications produced, and verify the usefulness of learning in dynamic geometry computer environments to improve students' proof skills.
教學單元	□數與運算(Number & Operations) □代數(Algebra) ■幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	Geometry problems. The teaching unit had as main objectives: 1. To facilitate the teaching of concepts, properties and methods usually found in the school plane geometry curriculum: Straight lines and angles among them. Properties and elements of triangles (perpendicular bisectors, angle bisectors, etc.). Congruence and similarity of triangles. Relationships among angles and/or other elements of a triangle. Quadrilaterals, their properties and elements. Classifications of triangles and quadrilaterals. Circles, angles and tangents. 2. To facilitate a better understanding by students of the need for and function of justifications in mathematics. 3. To facilitate and induce the progress of students toward types of justification closer to formal mathematical proofs. In terms of van Hiele levels, with respect to justifications, the objective was to help students to do, by the end of the experiment, justifications in, at least, the third level.
教育階段	□國小 ■國中 □高中 A group of 16 students in their 4th grade of Secondary School (aged 15–16 years)
融入教學之工具	Dynamic geometry software: Cabri-Géomètre
學習活動 (Learning activity)	教學策略: The teaching unit had 30 activities. Each activity was structured in several phases, beginning with a phase where students had to create a figure in Cabri and explore it (in a few activities the figure was provided by the teacher in a file to be opened by the students). In the second phase students had to generate conjectures (in some activities, the students were

	asked only to check a given conjecture). In the last phase students had to justify conjectures they had stated (some activities did not include this phase). Two 55-minute mathematics classes per week were devoted to the teaching experiment. Students worked on each activity during two consecutive classes, so the experiment lasted about 30 weeks. During the first class of an activity, the pairs of students worked autonomously in solving the activity. The teacher observed their work and answered their questions. By the end of this class, each pair had to give the teacher their results written on the worksheets, and also had to save their constructions in computer files. Each pair had to write one answer, agreed by both students. At the beginning of the second class, the teacher gave students a list with their different answers to the problem, and several students (selected by the teacher) presented their solutions to the group. Then, the class, guided by the teacher, discussed the solutions presented, the correctness of the conjectures and the validity of their justifications. Finally, the teacher made a summary of the activity and stated the new results students had to learn.
所收集之 研究資料	The answers to the test activities written by the two pairs of students on their worksheets, plus the files with constructions made in Cabri、To record interactions with Cabri of the two pairs of students、Three semi-structured clinical interviews to the two pairs of students selected.
研究結果	Students' movements from one phase of the solution of a problem to another describe the process of solution, since such movements are related to their success in finding a correct answer. T and P's solutions of the three problems are a clear example: In the first test activity, T and P were not able to leave the ascending phase, since their work was based only on identification of specific examples, and they did not find a valid conjecture. In the second test activity, they jumped several times between ascending and descending phases, since they first justified an auxiliary property and later they justified their conjecture. In the third test activity, T and P only jumped to the descending phase once, when they completed their experiments with specific examples and began to construct the correct figure. In second and third activities, T and P constructed several figures during the solution, but the difference was that in the second test activity intermediate drawings helped them discover valid properties or conjectures, that were justified in the descending phase, while in the third test activity they found counterexamples for their conjectures, eliminating the need for justifications in the descending phase.
科技工具之特點	1. A DGS like Cabri may well help secondary school students understand the need for abstract justifications and formal proofs in mathematics. Secondary school students cannot make a fast transition from empirical to abstract ways of conjecture and justification. Such transition is very slow, and has to be rooted on empirical methods used by students so far. In this context, DGS lets students make empirical explorations before trying to produce a deductive justification, by making meaningful representations of problems, experimenting, and getting immediate feedback. 2. Dragging is a unique feature of DGS (of Cabri in particular) that makes DGS environments much more powerful than traditional paper-and-pencil learning. Dragging lets students see as many examples as necessary in a few seconds, and provides them with immediate feedback that cannot be obtained from paper-and-pencil teaching. In our teaching experiment, dragging helped students to look for properties, special cases, counter-examples, etc. that could be linked to form a conjecture or a justification. In particular, the dragging test was used most of the times as the criterion to accept a figure as correct.

編號:1229

Data Extraction Form	
欄位名稱	內容
文獻來源	Jones, K. (2000). Providing a foundation for deductive reasoning: Students' interpretations when using dynamic geometry software and their evolving mathematical explanations. Educational Studies in Mathematics, 44(1-3), 55-85.
研究目的	This paper reports on data from a longitudinal study of 12-year-old students’ interpretations of geometrical objects and relationships when using dynamic geometry software. The focus of the paper is the progressive mathematisation of the student’s sense of the software, examining their interpretations and using the explanations that students give of the geometrical properties of various quadrilaterals that they construct as one indicator of this. The aim of the study reported in this paper is to contribute to what is known about enabling more students to successfully make this transition.
研究問題	This paper concentrates on how the students reason about geometrical objects and relations as they experience them through the dynamic geometry environment and how the mathematical explanations they offer evolve as they become more experienced both with geometry and with the software.
研究方法	The empirical work for this study was designed to be carried out in the UK and, following Hoyles (1997), the design was informed by the structure of the mathematics curriculum experienced by students in the UK.
教學單元	□數與運算(Number & Operations) □代數(Algebra) ■幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	Geometrical properties of various quadrilaterals: Some geometry topics involving area and volume, but not directly about the geometric properties of quadrilaterals.
教育階段	□國小 □國中 ■高中 Lower secondary (junior high) school students (aged 12 years old).
融入教學之工具	Dynamic geometry software：Cabri-géomètre version 1.7.
學習活動 (Learning activity)	教學策略: Small groups (of 3 to 6 students) on a range of problem-based tasks, some ‘real’ (and similar to those in the RME tradition) and some of a more ‘pure’ mathematical nature.
	A teaching unit was developed in collaboration with the teacher of the class that would address the properties of quadrilaterals and could be accommodated in the regular routine of the class. As pairs of students took turns in using the computers, there might be gaps of up to a week between sessions that any particular pair of students had using the software. The teaching unit was prepared to form three phases. During each of the phases, the students worked in pairs (usually the pairs they worked in for all their mathematics work). ＊Phase 1: The students gained preliminary experience with Cabrigéomètre while working through a short series of tasks involving lines and circles. The aim of the phase was for students to acquire familiarity with the software interface and be introduced to the constraint of robustness of a figure under drag. For each task (in phase 1 and in the subsequent phases) the challenge for the students was to reproduce, using the software, a figure identical to one provided on paper but which could not be ‘messed up’. The tasks used in each of the three phases of the study were so designed that to successfully meet the challenge of

	constructing the figures so that they are invariant under drag, the students have to analyse the spatial arrangements (taken as a form of mathematisation) and, as they are novices with the software, work out how to realise their constructions in the software environment in such a way that not only does it appear to be correct visually in a static form but that if any objects (such as points, lines or circles) used in the construction are dragged, the patterns remain consistent. For most students, phase 1 took up to three hours of using the software. ＊Phase 2 of the teaching unit involved the students working through a series of three tasks that required constructing the following quadrilaterals: A rhombus, a square, and a kite. Each task contained a visual prompt and the challenge to construct the figure so that it was invariant under drag and explain why the figure constructed is a particular quadrilateral. In consonance with the idea of progressive mathematisation, the tasks in phase 2 were designed with the intention that the students would become more adept at analysing the geometrical structure provided in the visual prompt and, by having done this. ＊Phase 3 of the teaching unit involved the students working through a series of six tasks that involved relationships between various quadrilaterals: Tthe rhombus and the square, the rectangle and the square, the kite and the rhombus, the parallelogram and the trapezium, the rhombus, rectangle and the parallelogram. Most of the students took up to three hours on this phase of the teaching unit. For each task, the students were provided with a visual prompt. The sixth and final task of phase 3 asked the students to complete a hierarchical (inclusive) classification of the 'family' of quadrilaterals and explaining the relationships within this 'family'. In this final task the phrasing used was that a particular quadrilateral (say a square) was "a special case" of another quadrilateral. This phrasing was chosen as another way of expressing inclusive mathematical classification. Through the use of these different phrasings (that all squares are rectangles, and that a square is a special case of a rectangle) an attempt was made to take account of what Hershkowitz (1990, p. 81) calls "the opposing direction inclusion relationship" between sets and subsets of examples of, say, quadrilaterals, on the one hand, and the sets and subsets of their attributes on the other. The impact of this opposing direction inclusion relationship is that, for example, young children may not entertain a square as a quadrilateral because a square has four equal sides while other quadrilaterals do not.
所收集之 研究資料	Video and additional audio tape to capture the onscreen work and student-student\and student-teacher interactions, student written work (unaided), student software files, the 'history' of the student constructions using the software (a feature available with the particular software), and researcher field-notes.
研究結果	The research study reported in this paper also reveals the mediational impact of using dynamic geometry software. As documented by this study (and by other research referred to in this paper), this mediational impact was in terms of the following: 1. The students' understanding that the order in which objects were created leads to a hierarchy of functional dependency within a figure. 2. The constraint of robustness of a figure under drag becoming linked with using points of intersection to try to hold the figure together. 3. The 'dynamic' nature of the software influencing the form of explanation given by the students. Thus, when using dynamic geometry software, students need to come to terms with the notion of a hierarchy of functional dependency within a figure. The students need to gain an appreciation of the notion of the constraint of robustness of a figure under drag as a mathematical feature, rather than, say, as 'mechanical glue'. The 'dynamic' nature of the

	software influences the form of explanation given by the students.
科技工具之特點	Using dynamic geometry software does provide students with access to the world of geometrical theorems but it is access that is mediated by features of the software environment, certainly in the vital early and intermediate stages of using the software.

編號:1237

欄位名稱	
文獻來源	內容
研究目的	Sinclair, M.P.(2003). Some implications of the results of a case study for the design of pre-constructed, dynamic geometry sketches and accompanying materials. Educational Studies in Mathematics, 52(3),289-317.
研究問題	The study that informs this article was undertaken to investigate the benefits and limitations of using pre-constructed, web-based, dynamic geometry sketches in activities related to deductive proof at the secondary school level. Two distinct themes emerged from analysis of the results – first, the relationship between the activities and the development of geometric thinking skills, and second, the relationship between the design and use of the materials, and the exploration process. This article focuses on the latter. The activities for the study were designed to help students notice geometric details, explore relationships, and develop reasoning skills related to geometric proof.
研究方法	The research used a case study approach and multiple sources of information– observation field notes, videotape, audiotape, a student questionnaire, and interviews with teachers. Collected data were transcribed, then analysed by coding, developing categories, describing relationships, and applying simple statistical tests where appropriate.
教學單元	□數與運算(Number & Operations) □代數(Algebra) ■幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	The study focused on the topic of congruence and parallelism, which was part of the geometry section.
教育階段	□國小 □國中■高中 Sixty-nine students, aged seventeen to eighteen, in three classes – class A from school S1, and classes B and C from school S2 – participated in this study.
融入教學之工具	Dynamic software：Pre-constructed, web-based dynamic geometry sketches share some features with sketches pre-constructed with Cabri Géomètre, or The Geometer's Sketchpad.
學習活動 (Learning activity)	教學策略: Students worked in pairs. In each class, several pairs were studied in more depth by audiotaping or videotaping their activities. The students in the taped pairs were chosen by the teacher to represent the range of achievement levels within the class, but students in any particular pair were not necessarily at the same achievement level. Students were asked to prove triangles congruent, to prove altitudes equal, and to investigate the question, When do the diagonals of a parallelogram bisect one another. Each labsheet included: directions for opening and manipulating the sketch, a statement of the problem, and questions related to the task. Overview of session tasks: Three 75 minutes sessions or four 45 minutes sessions were held with each class. During this time, student pairs worked on four tasks. An additional task was done as a whole class activity. A very brief overview of the four main tasks and one of the extra tasks is included here to help the reader follow the discussion. ＊Day 1, task 1 This sketch was developed to introduce students to JavaSketchpad, and specifically, to address student difficulties with overlapping figures and selection of triangles. In the sketch, ABC and FCB are reflections of one another in the perpendicular bisector of BC, which can be toggled on

	or off using the 'Show perpendicular through H' and 'Hide' buttons. When the sketch is first opened, point A is red, indicating that it can be manipulated. As point A is dragged, point F undergoes opposite motion as a reflection should. The two triangles ABC and FCB can be separated using an action button with label, 'Separate ABC and FCB'. The button, 'Show reflection and mirror,' reflects triangle ABC in a red mirror line. The button, 'Match FCB and A'B'C' causes triangle FCB to move on top of the reflection of triangle ABC, demonstrating congruency. A reset button is provided to move triangle FCB to its original position. The 'Show Given Information' button controls the display of the markings that indicate the equality of AB and FC, and ABC and FCB, as well as the measures of these lengths and angles. As a vertex of the figure is dragged, the measurements update. The labsheet for Day 1, task 2 (see Appendix A) asked students to prove ABC congruent to FCB. The proof could be carried out by a straightforward application of the SSS (side, side, side) congruency theorem; the task aimed to help students select the correct sides by providing the tools to separate and reorient the triangles, and by asking specific questions about observations and results. ＊Day 1, task 2 The second task for day 1 was designed to address student difficulties with overlapping triangles, selection of triangles, and two-step proofs. All triangle pairs that could be selected were reflections, and congruency could be established or not established by considering what would happen if one member of the pair was flipped over. For example, triangle BEF and BDF can be shown to be congruent using SSS. This implies that BF is a line of reflection. If BD and EF are produced to intersect at A, then by the properties of reflection we know that BC is equal to BA and FC to FA. Since the curriculum focuses on Euclidean proof, study students were not able to compose a transformation argument such as this; however, their awareness of symmetry as shown later in this article suggests that they were ready to consider such an option. This task inadvertently introduced an element of uncertainty, by including one pair of triangles (BAF, BCF) that could not be proven congruent with the given information (i.e., in two steps, although the congruency could be established through carrying out an additional congruency proof). This is not usually done in textbook problems. It was expected that students would prove the pairs congruent in the following ways: BDF, BEF – SSS; ADE, CED – ASA; BDC, BEA – ASA. The labsheet encouraged students to examine each pair by using the separate, join, and hide/show commands. ＊Day 2, task 1 This task gave students the opportunity to apply properties of parallel lines and to investigate a problem using a rotation. The triangles to be proven congruent were coloured to attract student attention. When a vertex of quadrilateral ABCD was dragged, AD and BC appeared to remain equal and parallel, as did AB and DC. When the 'Show Given Information' button was used, students could deduce that ABCD was indeed a parallelogram since opposite sides were marked equal. It was expected that students would use ASA (angle, side, angle congruency theorem) to prove that _AMD and _BNC were congruent: AD = BC (given), _ DAM= _ BCN (parallel line law), and _ MDA = _ NBC; however, students could also investigate the relationship between the two by superimposing an additional given triangle over _ABC and then rotating it to fit over _CDA. This movable triangle was a tool for testing whether _AMD and _BNC were congruent; however, it could also be used to demonstrate the fact that congruent triangles have congruent altitudes (i.e., _ABC and _ADC are congruent, which implies that AM must equal BN). Questions on the labsheet such as: "What do you notice

	about the new triangle?" and "How can the information provided by these images be used to explain why DM = BN?", were aimed at helping students notice and address the information provided in the sketch. ＊Day 2, task 2 This task was designed to help students investigate the question: "When do the diagonals of a parallelogram right bisect one another?" The sketch included parallelogram ABCD, with diagonals AC and BD. The opposite sides were marked with arrows, the traditional markings for parallel lines. Measurements of the sides, diagonals, and semi-diagonals could be toggled on or off using Show/Hide buttons. Since it can be frustrating to drag an angle until the measurement is precisely 90◦, the button 'Show Perpendicular' produced a line perpendicular to AC. Students could drag the diagram until BD was aligned with the perpendicular – a slightly easier task. Day 2, task 2 was undertaken after a short class session on conjecturing. Since the task involved knowing the term 'right bisector', the first section of the labsheet asked questions about the meaning of 'bisect', 'right bisect', and 'right bisect one another'. The labsheet then asked students to drag the diagram and to conjecture a response, to develop a proof of the conjecture and then to outline an alternate proof. ＊Day 1, task 3 One of the extra tasks provided for students who finished early, Day 1, task 3, invited students to examine a sketch that looked like two nested isosceles triangles JCL and ECG. It asked the students to prove that triangle CJL was isosceles. When the sketch was opened J, E, G, and L were collinear; however, students were able, using the Show More button, to examine a second situation in which these points were not collinear, and thus to consider why it is important to clarify initial assumptions. If the points are collinear, then the two triangles are isosceles. If the points are not, then the outer figure is not even a triangle.
所收集之 研究資料	Observation field notes, videotape, audiotape, a student questionnaire, and interviews with teachers.
研究結果	An analysis of the data showed that task question and sketch provision must work together to create an environment for exploration. It also indicated that explicit attention to visual interpretation and exploration using change is required in order for students to benefit fully from their experiences with pre-constructed dynamic geometry sketches. The following analysis looks at the data regarding the study materials from two perspectives: 1. How students responded to particular question 'types' and sketch provisions. 2. How particular results highlighted elements that were missing (and needed) or poorly designed. ＊Noticing Colour drew attention – students noticed items that were coloured and sometimes missed those that weren't. The ability to toggle colours off and on helped students to select and describe particular figures. Colour was also used as a simple and effective means of referencing objects in discussion. The ability to display an accurate image is commonly assumed to be a benefit of dynamic geometry software – it seems reasonable to conclude that the task of noticing and interpreting relationships between objects is easier if figures are drawn to scale. However, the study results showed that students do not automatically understand that the onscreen image is accurate →the tendency of study s.tudents to gloss over measurements is in stark contrast to their awareness of colour and motion. It is of concern because the ability to explore using change requires focused attention to details that update under the operation of dragging.

	＊Taking action Once students have focused their attention on a particular object they need to do something meaningful. All students responded to this type of question/instruction by examining the sketch and discussing their answers. The pre-constructed web-based sketches supported their investigations by providing dragging capabilities, onscreen data, and familiar labels and marks. →the study results show that students usually stopped dragging after a short time and concentrated on interpreting the static figure. I believe this indicates several things: (1) that the provision of the dragging capability is not enough to help students interpret pre-constructed dynamic figures and that in order to make effective use of dynamic diagrams students must be able to direct their use of dragging, i.e., they must learn to use change to explore; and (2) that task designers must focus on developing questions specifically about the motion. ＊Surprise One question which was only intended to prompt students to gather evidence for congruency generated a great deal of discussion and investigation. In fact, there were not always three pieces of information – a situation that created uncertainty and surprise. It was this 'rug-pulling' question that first made me aware of the strong relationship between students and materials.While surprise can be a powerful way to engage students, if this surprise is initiated by a dynamic image – especially one that the student did not construct–in a non-teacher directed activity, materials should incorporate some question or statement that hints at the possibility of a surprising result to avoid causing undue frustration for students. ＊Inviting Inviting questions such as the following, were more open-ended than the prompting questions mentioned earlier. These questions asked students to use their observation and interpretation skills, and to look at the problem from a different perspective. To answer, students needed to explore alternative paths. The need for alternatives highlights an important design consideration. In order for students to explore uncharted territory, a pre-constructed web-based sketch must provide options. Nevertheless, providing options is only part of the issue. All of the study sketches could be dragged into configurations that went well beyond the needs of the particular assignment. Measurements of various sides and angles were provided, even when they were not strictly required. And although students usually carried out traditional congruency proofs, all sketches could be explored via transformation relationships. However, many students did not know how to make use of these provisions. I contend that this problem had nothing to do with their computer skills and everything to do with their inability to pose their own questions. Help students move through an investigation the task creator can include (1) General exploration directives and suggestions, especially those related to using motion. (2) Statements that encourage students to pose their own questions about visual information. ＊Transformations and visual ideas Many students showed that they appreciated the significance of reflections in this sketch; nevertheless they were unable to construct a satisfactory transformation-based explanation in answering the question. These impoverished conversations about transformations highlight students' unfamiliarity with describing visual information in precise terms. The study students had worked on symmetry and transformations

	in earlier grades, but most of the emphasis had been on recognising and reproducing transformed shapes; the development of deductive proof had avoided transformations completely. The experience of the study students is not atypical. In the study sketches, transformation capabilities, while interesting to students, were not as effective as I had hoped in helping students develop their geometric skills because labsheet questions – and the students' curriculum – emphasised Euclidean-based methods. If we want to encourage transformation-based approaches to working with dynamic sketches methods must be developed to help students: (1) Learn to use transformation concepts to monitor how isual elements are changing in relation to one another, (2) Develop facility in writing transformation-based proofs. ＊Explaining Every labsheet included questions that asked students to explain their reasoning, but responses were usually sparse. ＊Avoiding trivial responses Some questions on labsheets were more effective than others. The study students did offer trivial responses, but I contend that instead of a simplification of the mathematics, they needed explicit work on visual reasoning skills to help them focus on details, follow chosen elements across the screen, and use transformation concepts and other mathematical principles to organise information. ＊Sketch-Labsheet links Study results show that the materials used in a geometry investigation involving pre-constructed sketches strongly impact the student. If we examine each statement or question in a task in terms of its function we find that some closely parallel the interventions used by a teacher. →provisions that will help students learn how to use change to explore, and how to extend their visual interpretation skills. An analysis of the data showed that task question and sketch provision must work together to create an environment for exploration. In addition, student responses clearly indicate that explicit attention to visual interpretation and exploration using change is required in order for students to benefit fully from their experiences with pre-constructed dynamic geometry sketches.
科技工具之特點	1.A sketch allowed students to use rotation to explain why two segments were equal, instead of deducing the result via a triangle congruency proof 2. A pre-constructed web-based sketch must provide options. All of the study sketches could be dragged into configurations that went well beyond the needs of the particular assignment. Measurements of various sides and angles were provided, even when they were not strictly required. 3.Using transformation relationships to organise dynamic visual information. Since transformations can help us make sense of what we are viewing, they should be emphasised in any dynamic task.

編號:1252

Data Extraction Form	
欄位名稱	內容
文獻來源	Kordaki, M. (2003). The effect of tools of a computer microworld on students' strategies regarding the concept of conservation of area. Educational Studies in Mathematics, 52(2), 177-209.
研究目的	In this paper, the effect of the tools of this microworld on students' constructions is investigated. More specifically, I explore the following: 1.Students' strategies regarding the concept of conservation of area and their development while interacting in the context of the computer microworld; 2.Students' thinking on the concept of conservation of area in classes of equivalent triangles and parallelograms with common bases and equal heights; 3. The role of the tools that are offered by the computer microworld regarding students' strategies. This study focuses on students' approaches (in the sense of students' conceptions) to the concept of conservation of area used in their strategies in solving the problems of transformation and of comparison within the context of the C.AR.ME. microworld. This work is part of an extensive formative evaluation of the above microworld designed to investigate students' strategies related to the concepts of conservation of area and its measurement.
研究問題	
研究方法	In terms of methodology it is a qualitative study as well as adopting a phenomeno graphic approach to evaluation. In interpreting this approach I focus on the variety of relations/interactions realized by the students with the tools of C.AR.ME. as well as on the different ways that these students approach the concept of conservation of area using these tools.
教學單元	□數與運算(Number & Operations) □代數(Algebra) ■幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	Transform the polygon
教育階段	□國小 ■國中 □高中 Secondary school of Patras, Greece. A complete class consisting of thirty 2nd grade students (14-year-old) participated in a problem-solving activity.
融入教學之工具	The 'Conservation of Area and its Measurement' (C.AR.ME.) microworld：has been designed as an interactive, open, problem solving and exploratory environment to support students in constructing actively their own approaches to the concepts of conservation of area and its measurement. In this context a variety of tasks can be posed by the teacher and a number of different epresentations of the above concepts can be constructed or explored by the students. The microworld intends to encourage students to be responsible for their learning process, by not providing the 'right' answers but by offering intrinsic visual feedback to their actions.
學習活動 (Learning activity)	教學策略:建構式學習
	＊This activity involved the conservation of area and its measurement concepts and was not part of students' normal classroom experience. In this experiment students were asked to face two tasks in the context of C.AR.ME. The duration of each task was commensurate with the students' needs. Each student spent on average about two hours per task. A familiarization phase using the tools of C.AR.ME, took place before the students commenced the main study. The aim was to familiarize the

	students with the tools of the microworld and not to get them involved in the solving of specific task processes. The need for this phase emerged from the pilot study and was realized by asking the students to try consecutively all the operations provided by this microworld. For example, 'draw a polygon', 'draw a segment', 'save your work', 'rotate a shape', 'select the rectangular grid', 'copy a shape', 'paste a shape' were some typical examples of the tasks posed. Students worked in a computer laboratory, consisting of three computers where they worked in rotation. They worked individually except during the familiarization phase where they worked in pairs. The researcher participated in the study as an observer with minimum intervention. All interventions realized by the researcher are reported with reference to the specific cases in the results section of this paper. The whole learning context consisted of the computer environment, the researcher, the students and the tasks they performed during the experiment. ＊The tasks Two tasks were assigned to the students during this evaluation study. The first was the task of transformation of a non-convex polygon to another polygon with equal area and the second was the comparison of a non-convex polygon to a square, not easily comparable by 'eye'. All the shapes to be studied were drawn on the computer screen by the researcher, and the instructions were presented verbally to the students. In the first task students were asked to: "transform this polygon into another polygon with equal area in any possible way". Those students who automatically transformed the non-convex polygon into other equivalent geometrical shapes or classes of shapes of the same form were asked: a) "what do you think about the areas of these shapes?", "are they equal or not?", "justify your answer". These questions were asked to give students the opportunity to express their thinking about the concept of conservation of area in classes of equivalent parallelograms and of triangles with common bases and equal heights. For those students who did not use these automatic transformations, the researcher intervened by performing them. Then these students were also asked the questions mentioned above. By allowing and asking for a variety of solutions to the given tasks students were encouraged to construct their own individual approaches to the concepts of conservation of area and its measurement and to express different areas of knowledge they possess regarding these concepts. The above tasks have been considered by other researchers as essential for the students to construct in a qualitative way the concepts of conservation of area and its measurement. The nature of these tasks allows the students to construct their own individual approaches to the relative concepts, to express their intuitive knowledge as well as to develop multiple and different solution strategies.
所收集之 研究資料	The data resources are the log files containing the history of students' interactions with the tools of C.AR.ME., the electronic snapshots of students drawings, the audio recordings of all verbal interactions and the field notes of the researcher
研究結果	＊Categories of students' strategies G1: Transforming and comparing areas by using the tools for automatic transformations. Students transformed the non-convex polygon by performing the following strategies. G2: Transforming and comparing areas by using the tools that simulated the students' sensory-motor actions. Most students (27 students) transformed the non-convex polygon by performing strategies included in this category. G3. Transforming and comparing areas by using the tools that simulate the students' sensory-motor actions in combination with the tools for automatic transformations.

	G4. Transforming areas by using the tools that support the operation of area measurement using spatial units in combination with the tools for automatic transformations. G5. Transforming areas by enclosing the non-convex polygon in its minimum convex super set using the drawing tools in combination with tools that simulate the students' sensory-motor actions. G6. Transforming areas by enclosing the non-convex polygon in its minimum convex super set using the drawing tools in combination with the simulations of students sensory-motor actions and the tools for automatic transformations. G7. Comparing areas by enclosing the non-convex polygon in a minimum rectangular/square super set in combination with the operation of area measurement using spatial units. G8. Transforming and comparing areas by enclosing the non-convex polygon in a minimum convex super set using the drawing tools in combination with the operation of area measurement using spatial units and area formulae. G9. Transforming areas by using the automatic area measurement operation in combination with the area formulae and automatic transformations. ＊Students' strategies across categories These strategies were developed mainly later on during the process of students' involvement in both tasks and show students' mathematical progression regarding the concept of conservation of area to a more advanced level. In my view, this fact shows, that the nature of these tasks in which students are asked to solve them 'in any possible way' and the availability of a variety of tools that support the construction of different solution strategies of the same problem, can inspire the students to move to more advanced mathematical constructions regarding the above concept.The analysis of students' work illuminated the possibilities of the tools of the microworld providing students with the opportunity of exploring this concept in specific classes of equivalent shapes, of expressing their own knowledge to this concept, of expressing different pieces of knowledge they possess constructing a variety of approaches, of building interrelationships between the various aspects of area and overcoming certain difficulties. It also shows the important role of the tasks that the teacher can plan to support students' involvement in this environment.
科技工具之特點	1. Tools that simulate the students' sensory-motor actions. These tools can be used for conserving areas by manipulating them without the use of numbers. A variety of different representations of equivalent areas can be created in two ways: first, by changing only the position of a figure while conserving its shape and second, by splitting a figure into its non overlapping parts and recomposing the parts to form a new equivalent shape. 2. Tools for automatic transformations. A number of different tools (presented under the 'Automatic Transformations' column) are provided for the students to automatically transform areas already drawn, to equivalent ones. The above tools were designed to help students to study the concept of conservation of area in a dynamic way. Students can draw the base of a representative for each one of the above classes using the drawing tools of C.AR.ME. Then, students can produce a number of equivalent shapes belonging to each class by using the appropriate tools. By altering these bases, a number of different classes of equivalent shapes of the same form can be produced. 3. The use of area measurement tools: Tools to construct a variety of spatial units and grids. Students used these tools to conserve areas in a more sophisticated way by splitting them into

	equal parts and recomposing them to produce equal areas. By experiencing the above concept using different units or grids as representation systems, students were helped to form this concept in a more abstract way.

編號:1303

Data Extraction Form	
欄位名稱	內容
文獻來源	Abu-Naja, M. (2008). The influence of graphic calculators on secondary school pupils' ways of thinking about the topic " Positivity and negativity of functions". International Journal for Technology in Mathematics Education, 15(3), 103-118.
研究目的	Our research project examined the effects of graphic calculators amongst ninth grade pupils from Arab society in the Negev area in Israel. The goal of this research was to discover and characterise the ways of thinking in this population about the concept of positivity and negativity of functions.
研究問題	
研究方法	To perform this investigation we compared two groups of pupils: the experimental group (n = 95) studied the topic by means of graphic calculators, while the control group (n = 89) studied the same topic in the traditional way. For the purpose of this research we developed a questionnaire based on the material studied in class, such that each question could be answered using either method.
教學單元	□數與運算(Number & Operations) ■代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	Graphs and function(圖形與方程式)
教育階段	□國小 ■國中 □高中 Ninth grade (secondary school)
融入教學之工具	Graphic calculators
學習活動 (Learning activity)	教學策略:
	＊The experimental group: The pupils studied the following topics related to the concept of function with the aid of graphic calculators ：drawing graphs of functions, findings the zero points of functions, determining the domain of positivity and negativity of functions. An examination of graphs of functions by means of the ”trace” operation enables the presentation of values of the function at all points where the trace is performed. Pupils from the experimental group were loaned graphic calculators for their use during the entire year. They received guidance and encouragement in the use of the graphic calculators during mathematics lessons, for homework and while solving the questions of the questionnaire. ＊The control group: Studied the same subjects in the traditional way(without graphic calculators). They prepared table of values in order to plot the points of graphs of functions, performance of calculators to fill the table. Errors in calculations cause the production of incorrect graphs and also incorrect conclusions for these graphs. The time spent in drawing functions was less than that of the experimental group, because drawing of functions required more time for performing the calculations.
所收集之研究資料	Questionnaire(pupils’ responses)
研究結果	The pupils in the experimental group understood the concept of positivity and negativity of functions better than did the pupils of the control group. We found that the use of graphic calculators encourages the development of significant thinking. 1. The graphic calculator helps the pupils determine numbers whose image is negative(or positive below). Use of the “trace” cursor enables tracing over the surface of the graph of the function and obtaining the

	values of x and y for each point on the graph. 2. This apparently indicates that study with the aid of graphic calculators helps the pupils locate the intersection of the graphs with the axes when the graph is provided. 3. The use of graphic calculators gives an advantage over the traditional method in the execution of tasks when the graph of the function is provided to the pupils. 4. The pupils from the experimental group had the opportunity to see the function in several windows, as desired. It is also possible to view the table of values on the screen of the calculator, which gives the values of x and y in steps determined by the user at any time required. These are likely to aid the pupils of the experimental group to think about the "life " of the function beyond the provided drawing. 5. That study with the aid of graphic calculators does not give any advantage over the traditional method when the question is about a part of the graph of the function which is beyond the domain provided. Pupils from the experimental group did not think of the "life" of the function beyond the drawing give any more than did the pupils of the control group.
科技工具之特點	1. The aid of graphic calculators helps the pupils locate the intersection of the graphs with the axes when the is provided. 2. Pupils who used graphic calculators could see parts of the graph in several windows, whose dimensions could be determined by the pupils, at any time as needed. The technological possibility allows the pupils to see the values of the function in more than one winds.

編號:1358

Data Extraction Form	
欄位名稱	內容
文獻來源	Guven, B. (2012). Using dynamic geometry software to improve eight grade students' understanding of transformation geometry. Australasian Journal of Educational Technology, 28(2), 364-382.
研究目的	The purpose of this study is to determine the effect of the DGS Cabri (http://www.cabri.com/, Turkish language version) on eighth grade students' academic achievement and levels of understanding in transformation geometry.
研究問題	What is the effect of using DGS on eight grade students' academic achievement and levels of understanding of geometric transformations compared to paper and pencil methods?
研究方法	1. A pre- and post-test quasi-experimental design. 2.The experimental group：was taught using DGS the control group：was taught using isometric and dotted worksheets.
教學單元	□數與運算(Number & Operations) □代數(Algebra) ■幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	Transformation geometry
教育階段	□國小 ■國中 □高中
融入教學之工具	Dynamic geometry software: Cabri
學習活動 (Learning activity)	教學策略：Exploratory approach
	1. Before the treatment, students in the DGS group were trained on how to use Cabri software since it was new for them. Students learned the functions of the buttons, such as how to draw a line, segment, and form a polygon etc.; how to drag and construct bisectors; and how to measure length, area, angle, etc. 2. The teacher spent four class hours on teaching Cabri. During this four hour period, no application regarding geometric transformations was made with learners. Only technical characteristics and basic use of the software were summarised in the courses. 3. The students in this group used the features of Cabri software to study the worksheets that were handed out for lessons. Also, these students studied their own transformations on the computer independently from the worksheets. 4. Direct information was not presented on the worksheets which were given to students. The students were supposed to perform transformation applications and observe their effects. Also, they were supposed to write the observation results in the related places on the worksheets. In this group an exploratory approach was followed according to the features of transformation. During the course of application made with experimental group, learners studied in groups with two learners due to the limited number of computers. learners experienced: •Step by step construction of a transformation in the Cabri environment in accordance with the instructions written on worksheets. •Dynamic observation of the transformation by dragging geometric objects (e.g. changing symmetry line or point or rotation angle). •Exploring the characteristics of the transformation, confirmation of the exploration and explanation in the relevant section of the worksheet. •Discussion of the obtained results in the classroom. •Making the transformations written in worksheets according to the information obtained after classroom discussion and confirmation with Cabri. DGS was used as an instrument to explore the characteristics of the

	transformation, test the discovered characteristics and observe the transformation dynamically over the course of applications. Besides, learners were granted with the opportunity to practise and test what they learnt on computer screen and check their learning accordingly. In this process, the classroom teacher acted primarily as a facilitator with the role of organising the classroom discussions.
所收集之 研究資料	Transformation Geometry Achievement Test (TGAT)、 Learning Levels of Transformation Geometry Test (LLTGT))
研究結果	The result of covariance analysis showed that the experimental group outperformed the control group not only in academic achievement but also in levels of learning of transformation geometry.
科技工具之特點	1. The dynamic feature of the software enabled students to easily study the different type of transformations and observe the dynamic effects of change on the main object on the image object. 2. The processes of controlling of their own learning pace and carrying out their ideas and actions on a computer screen can positively affect students' learning. In the DGS learning environment students can easily change the symmetry lines, symmetry centre points, geometric shapes and rotation angles. They also can observe the effects of the changes on symmetry and enabled the students to understand and interiorise the nature of change. 3. Studying transformations designed by themselves without reference to worksheets, choosing and designing the elements necessary for performing a transformation on a computer screen such as screen angle measure and symmetry line, can lead students to develop an advanced understanding of transformation. 4. Students could define their mistakes by observing the coherence between the geometric shape they obtained on the computer screen and their expectations before the application. They received feedback from the computer and could discuss this feedback with the classroom teacher. 5. Students have opportunity to generate their own feedback on computer screens. 6. Students were able to make many different transformations on the same geometric shape in succession. Many students increased their competence in understanding combinations of transformations and making connections between transformations. 7.The opportunity to observe dynamically the features of geometric transformations in an exploratory environment increased students' understanding.

編號：1383

Data Extraction Form	
欄位名稱	內容
文獻來源	Roschelle, J., Rafanan, K., Bhanot, R., Estrella,G., Penuel, B., Nussbaum, M., Claro, S., (2010) Scaffolding Group Explanation and Feedback with Handheld Technology：Impact on Students' Mathematics Learning. In Educational Technology Research and Development, 58(4), 399-419.
研究目的	
研究問題	Will group-level feedback (as scaffolded by TechPALS' package of handheld software and Cooperagents training) increase student engagement in explaining mathematics to each other (and related positive social learning behaviors) and consequently increase student learning.
研究方法	＊We designed a randomized experiment. The study team randomly assigned students to solve fractions problems using either TechPALS or a commercial software application that provided students with solo practice opportunities with individual feedback. We compared TechPALS to alternative software so as to rule out the possibility that any differences in learning were caused by students' excitement about technology (a potential Hawthorne effect) and to make sure both conditions received feedback. For our control intervention, we selected iSucceed Math (formerly Larson Intermediate Math), a widely used commercial-grade software. To encourage TechPALS students to engage in explanation and other appropriate collaborative behaviors, we developed The Cooperagent, a short multimedia presentation and storybook about an agent who learns cooperative learning behaviors. The Cooperagent presents two scenarios showing Cooperagents, characters who are about 12 years old, in groups of three using key cooperative learning behaviors of asking and answering how and why questions while trying to solve math problems. The story's characters modeled and emphasized the importance of eliciting and providing explanations ("ask and answer how and why") rather than merely asking for and giving the answers. We introduced The Cooperagent in the beginning of the intervention and relied on teachers to reinforce the behaviors throughout the intervention. Students also received print collateral to which they could refer back.
教學單元	■數與運算(Number & Operations) □代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	Fractions
教育階段	■國小 □國中 □高中 We recruited two classrooms of fourth-grade students from each of three elementary schools.
融入教學之工具	The TechPALS intervention comprised a database of content specific to fractions, Eduinnova software for handheld devices, and training modules on cooperative learning for both teachers and students.
學習活動 (Learning activity)	教學策略: Cooperative learning
	＊For the portion of the class period devoted to student-centered practice, we randomly assigned half the students from one teacher to exchange classrooms with half the students from the second participating class. Students were given a pretest on the first day of the experiment and an identical posttest on the last day of the experiment, with approximately 12 days of instruction and practice in between. ＊Three activities drew our attention as fitting our target domain of fourth-grade fractions:

	Consensus, Exchange and Aiming Between. ＊Consensus In the Consensus activity, each student in the group of three receives the same multiple-choice question at the same time. Each student enters an answer independently (individual accountability); however, the system requires that students agree on an answer and provides feedback only at the group level. If students do not choose the same answer, the software tells them they must agree, which generates much discussion. Once students agree, the software tells them whether they were all right or all wrong (formative assessment). If wrong, they must try again, while the software makes the previously incorrect choice unavailable so that students individually select a different answer until they select the correct one. ＊Exchange In the Exchange activity, each student receives two representations of a fraction, such as a numeral representation and a pie representation. Each student's goal is to match the representations on his or her screen. A match is achieved if the representations depict equivalent fractions. To achieve a match, students exchange representations within their group (positive interdependence). When all three students think they have a match, they check their answer. Similar to Consensus, the software tells the students only that all the matches in the group are correct or that at least one student does not have a match (formative assessment). The students determine who has the mismatched representations. Because of the need to both exchange representations and find mismatches, students have to engage in cooperative negotiations. Further, because one student may have the numeral 5/6 and another student a pie showing 10 of 12 shaded sections, the students are encouraged to explain to each other why particular representations are or are not equivalent. ＊Aiming Between The Aiming Between activity consists of two parts: Generating a unique fraction and evaluating fractions on a number line. Each student in the group of three receives the same representation of a number line with a target interval highlighted. The number line always starts at 0 and ends at 1; however, it varies in terms of target interval length and location as well as the number of tick marks, which are always in equal intervals. Each student constructs a fraction that would fall within the highlighted target interval After each group member enters an answer independently (individual accountability), the system verifies that each student has submitted a unique fraction (equivalent fractions are accepted). If a group member enters an answer that was already given, the system instructs the member to submit a unique answer. Once each member submits a unique answer, the system allows the group to proceed to an evaluation screen. Each group member evaluates whether each of the three answers fall within or outside the target interval. The system instructs the group to come to a consensus whenever there is disagreement in the evaluation, and the activity proceeds much in the style of Consensus. Again, feedback occurs only at the group level; students must agree (positive interdependence); and the software indicates correctness while also providing the opportunity to revise incorrect responses (formative assessment).
所收集之 研究資料	Observation protocol、Student fractions knowledge test: Observed frequencies of behaviors and pre-post gain scores on the student fractions knowledge test. After discussing the equivalence of groups on the fractions test at pretest.
研究結果	1. Found that behaviors compatible with social processing of feedback occurred significantly more frequently in the TechPALS condition. These include reading a problem aloud, asking a mathematical question, giving

	an explanation, making a collaborative move, directing a peer, and disagreeing with another student. The only behavior that occurred significantly more often in the control condition was raising a hand (to call the teacher). Consequently, it seems plausible that any observed gains in the treatment group could be produced by an increase in social processing of group feedback, including such behaviors as asking a math question, giving and explanation, and discussing a disagreement. 2. Analysis of the impact of TechPALS on students' fractions knowledge：It is worth noting that the TechPALS condition supported learning for students with either low or high pretest scores. Students do not need high incoming content knowledge to benefit from small group work.
科技工具之特點	1. That TechPALS could benefit students because of its support for group feedback and social processing. Our observational measures support the interpretation that group feedback and social processing was a significant component of the intervention; feedback and social processing behaviors occurred far more frequently in the TechPALS condition than the control condition. 2. TechPALS using handhelds to scaffold small group learning may be an important approach to explore further, because technology can socialize learning, encouraging positive behaviors such as asking questions, giving explanations, and discussing disagreements. These social behaviors, in turn, may engage students in connecting conceptual and procedural aspects of mathematics content.

編號:1498

Data Extraction Form	
欄位名稱	內容
文獻來源	Ubuz, B., Üstün, I., & Erbaş, A. K. (2009). Effect of dynamic geometry environment on immediate and retention level achievements of seventh grade students. Eurasian Journal of Educational Research, (35), 147-164.
研究目的	The purpose of this study was to compare the effects of instruction utilizing a dynamic geometry environment (i.e., Geometer's Sketchpad) to traditional lecture-based instruction on seventh grade students' learning of line, angle, and polygon concepts.
研究問題	
研究方法	A pre-test, post-test and delayed-post-test experimental-control group design was utilized. One of the two seventh grade classes in an elementary school was randomly assigned as the experimental group and the other as the control group. There were 15 girls and 16 boys in the experimental group and 17 girls and 15 boys in the control group with ages ranging from 12 to 14 years. A geometry achievement test covering seventh grade geometry topics was prepared to investigate students' achievement in geometry. The pre-test was given prior to the intervention and two posttests after the intervention.
教學單元	□數與運算(Number & Operations) □代數(Algebra) ■幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	Line, angle, and polygon concepts.
教育階段	■國小□國中 □高中 63 seventh grade students in a public elementary school.
融入教學之工具	Geometer's Sketchpad
學習活動 (Learning activity)	教學策略：
	＊實驗組 The treatment in the dynamic instructional environment included exploring and manipulating geometric concepts (lines, angles, and polygons) based on productive three-way interactions among teacher, students, and computers through subsequent open-ended exploration activities, called sketchsheets. Students worked on these activities at computers provided at the computer lab. Treatment for the EG. Prior to the treatment, hands-on instruction and practice were given at the computer lab to familiarize the EG students and their mathematics teacher with GSP and its uses. A two-hour training session was adequate for the students as they had been taking the Computer Literacy course since the sixth grade. At the end of this training, all students were proficient at constructing points, lines, angles and polygons with GSP. The teacher, however, did not have as much computer experience. At the end of the training, the teacher was not yet proficient with Sketchpad, requiring additional GSP support during the study period. Thus, the EG students were co-taught by the second researcher and the classroom teacher. To control the implementation threat, the role of the researcher was limited to only providing technical assistance and guidance for the things that students wanted to do with GSP but were unable to do without additional assistance. No extra information or material was given to students by the researcher in the labs. This was crosschecked by the teacher, who was present at all of the computer labs. Students spent approximately four hours each week working with Geometer's Sketchpad, working for approximately three class hours in a computer lab and one hour in the classroom. Students worked in pairs at the computer lab where there were 18 computers arranged in a U-shape.

	Eighteen" sketchsheets" were developed by the first two researchers to be used in conjunction with GSP. The materials were designed to allow students to develop their own understandings of various geometric concepts through active exploration, manipulation and transformation of geometric shapes. The majority of the sketchsheets required students to work in an investigative manner, employing inquiry and guided-discovery techniques to uncover specific geometric relationships or small sets of properties. Sketchsheets were distributed to the students in each computer lab session. Students were asked to complete the sketchsheets with GSP, writing their findings directly on the sheets. After students completed their investigations, the researcher asked students to comment on their mathematics findings and conclusions. All alternative findings were written on the board so that the students could discuss and interpret classmates' results. This cycle was repeated for all sketchsheets. Following the class at the computer lab, the students and their teacher discussed findings from the computer-based activities. Afterwards, the teacher typically introduced new topics in the regular classroom. ＊控制組 The traditional instructional environment was based on the chapters related to lines, angles, and polygons from the textbook used by the seventh graders at the study site. Treatment for the CG. The general method of instruction used in the CG was traditional lecturing with the aid of the textbook. In general, the teacher explained the concepts by writing them on the board, then allowed students to copy them in their notebooks. At the beginning of each lesson, the classroom teacher always reviewed the previous lesson by writing the important rules, formulas, or procedures on the board. Then, the lesson continued with students completing exercises from a previous lesson or writing a new rule or a new definition. The teacher typically used a ruler to draw lines and a protractor to measure angles. Students mimicked these sketches, drawing them in their notebooks using the same instruments. For some exercises, student volunteers were called up to the board to show their solutions. This was typically followed by teacher-led discussions of student-generated solutions. The teacher assigned homework from the textbook each time a topic was completed. The students in both groups were taught the same content at the same pace for five weeks. Students met four times each week in four separate 40-minute sessions.
所收集之 研究資料	pre-test、post-test、delayed post-test.
研究結果	After controlling for initial differences, comparison of pretest and post-test scores indicated that the students in the experimental group significantly outperformed those instructed in the traditional environment. However, delayed post-test scores indicated that the achievement difference between the groups was not enduring. Furthermore, although female students retained their knowledge better than male students, no significant treatment×gender interaction was found.
科技工具之特點	During the treatment, students in the EG experienced numerous non-prototypical instances of shapes as they dragged and dropped objects within the DGS. By modifying the objects of the constructions, the students developed more mature understandings of connections between the figures and their properties while forming hierarchical relationships between different classes of shapes.

編號:1503

Data Extraction Form	
欄位名稱	內容
文獻來源	Lee, C. Y., & Chen, M. P. (2009). A computer game as a context for non-routine mathematical problem solving: The effects of type of question prompt and level of prior knowledge. Computers & Education, 52(3), 530-542.
研究目的	The purpose of this study was to investigate the effects of type of question prompt and level of prior knowledge on non-routine mathematical problem solving. A computer game was blended within the pattern reasoning tasks, along with question prompts, in order to demonstrate and enhance the connections between viable problem-solving strategies and the content knowledge in a visible manner. The question prompts in this study referred to a set of questions that were domain specific and metacognitive-like, prompting students to attend to important aspects of a problem at different phases and assisting them to plan, monitor, and evaluate the solution process.
研究問題	The study examined the following questions: 1. Does the combination of question prompts and prior knowledge have an affect on students' problem-solving performances in non-routine mathematical tasks? 2. Does the use of specific prompts have more positive effect than general prompts on students' problem-solving performances in non-routine mathematical tasks? 3. Do students with high prior knowledge outperform those with low prior knowledge on their problem-solving performances in non-routine mathematical tasks?
研究方法	A quasi-experimental, 2 x 2 (question prompts prior knowledge) factorial, design was employed to investigate the impact of question prompts and prior knowledge on students' non-routine mathematical problem-solving performances. Participants were randomly assigned to the specific-prompt group and the general-prompt group to receive the one-hour weekly treatment. In the general-prompt group, procedural prompts were offered to help students complete the basic procedures of non-routine problem solving, while in the specific-prompt group, the supplementary elaboration and reflection prompts strongly related with the major tasks were provided to prompt students to articulate thoughts and elicit explanations.
教學單元	■數與運算(Number & Operations) □代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	applications of pattern reasoning and arithmetic sequences
教育階段	□國小 ■國中 □高中 Seventy-eight 9th graders from two classes of a public junior high school.
融入教學之工具	Problem-solving gaming model with reflection support (PSG)
學習活動 (Learning activity)	教學策略: Non-routine mathematical problem solving.
	＊Two major tasks Task 1: If there are n frogs in the left group and n frogs in the right group, how many times do you move the frogs to finish the game? Task 2: If there are n frogs in the left group and m frogs in the right group, how many times do you move the frogs to finish the game? ＊The purpose of Task 1 :was to evaluate students' predictions, generalization, and proof for pattern reasoning. Task 2 :was to evaluate students' pattern reasoning for two variables and

	the application of comprehensive comparison after getting an algebraic expression.. ＊Under the instructor's guidance, all participants finished the corresponding worksheets in accordance with the tasks and prompts given by the teaching websites. After the participants finished the task, they had to send their worksheets to the teacher. Then solutions could be provided for each prompt and the next task would be carried on. Therefore, participants' problem-solving performances could be measured based on the evaluation of these worksheets. Students' mathematics average score of previous five semesters in junior high school (CMA) was collected prior to the treatment. The teacher administered the MAS and PRT as the pretests. Participants were randomly assigned into two groups, the specific-prompt group and the general-prompt group. The experimental study was administered by the researcher and one of his colleagues in six sessions allotted equally to six weeks. All the study sessions were conducted in a classroom equipped with personal computers and the LCD projector. At the beginning, the participants were told to work on the frog leaping online game and to find the solution. The tasks and the question prompts were posted on the teaching websites. General prompts were provided to the general-prompt group while specific prompts were given to the specific-prompt group. At the same time, students needed to fill in the worksheets separately designed for the two groups. The participants followed the question prompts and the teacher's guidance to finish the two tasks and reported their findings on their worksheets. Then their worksheets could be evaluated by the teacher to get the scores for students' problem-solving performances.
所收集之 研究資料	Pattern reasoning test (PRT)、Mathematical attitude scale (MAS)、
研究結果	The results revealed that (a) the interaction of question prompts and prior knowledge was not significant, and (b) for the problem-solving performances, the specific- prompt group outperformed the general-prompt group and the high prior-knowledge group outperformed the low prior-knowledge group. Further, students receiving specific prompts outperformed those receiving general prompts in the problem-solving performance: reasoning for two variables. Students with high prior knowledge outperformed those with low prior knowledge in the two problem-solving performances: reasoning for one variable and reasoning for two variables. It was also found that prior knowledge and comprehensive mathematical ability were important predictors for the two problem-solving performances: reasoning for one variable and reasoning for two variables. However question prompts and mathematics attitude were not significant predictors for predicting the problem-solving performance of reasoning for one variable. Lastly, implications for these results and recommendations for future research were discussed. 1. This means that the effect of question prompts in problem-solving performances was not significantly different for the high prior knowledge students than it was for the low prior knowledge counterparts. Therefore, the combination of question prompts and prior knowledge did not have an affect on students' problem-solving performances in non-routine mathematical tasks. 2. It implies that different types of question prompts influenced students' problem-solving performances. Therefore, the use of specific prompts had more positive effect than general prompts on students' problem-solving performances in non-routine mathematical tasks. 3. It shows that overall prior knowledge influenced students' problem-solving performances. Therefore students with high prior knowledge outperformed those with low prior knowledge on their

	problem-solving performances in non-routine mathematical tasks. Further, univariate tests of between-subjects effects revealed significant effects of prior knowledge in the following two problem-solving performances, reasoning for one variable and reasoning for two variables. A stepwise multiple regression method was utilized to construct regression models to predict students' problem-solving performances by using prior knowledge, comprehensive mathematical ability, mathematical attitude, and question prompts as predictors. The regression results indicated that prior knowledge and comprehensive mathematical ability were important predictors on the two problem-solving performances: reasoning for one variable and reasoning for two variables. Finally, question prompts and mathematics attitude were the significant predictors on predicting only one problem-solving performance: reasoning for two variables. In another word, question prompts and mathematics attitude did not significantly predict the problem-solving performance, reasoning for one variable. ＊In this study, four findings were concluded. Firstly, regardless of the simple task (Task 1) or difficult task (Task 2), students with high prior knowledge outperformed those with low prior knowledge in problem-solving performances. Secondly, specific prompts did not have a more positive effect than general prompts in solving the simple task (Task 1). Thirdly, students receiving specific prompts outperformed those receiving general prompts in performing the difficult task (Task 2).Finally, question prompts and mathematics attitude were not the significant predictors on predicting the problem-solving performance of simple task (Task 1) but they could predict the problem-solving performance of difficult task (Task 2).
科技工具之特點	1. This indicated that specific prompts provided more explicit representatio might concentrate their more attention on the effective and correct ways to problem solving than those in the general-prompt group. Specific prompts provided more substantial efforts of instruction to bridge the gap between students' prior knowledge and non-routine problem-solving skills when executing more difficult and complex tasks. Therefore specific prompts should be designed to enable students to apply and adapt a variety of appropriate strategies to solve problems as well as to use representations to model and interpret physical, social, and mathematical phenomena

編號:1873

Data Extraction Form	
欄位名稱	內容
文獻來源	Forster, P. A. (2007). Technologies for teaching and learning about box plots and statistical analysis. International Journal for Technology in Mathematics Education, 14(3), 137-146.
研究目的	The purpose of the study reported in this section of the paper was to investigate the use of technologies for teaching and learning statistics.
研究問題	
研究方法	Two teachers and their Applicable Mathematics' class for 17 year old students participated. The teachers were selected because they had extensive experience in teaching with technologies and their past students had a record of achieving high scores in public examinations. The classes were in different All-girl schools. Data were collected during units of work on descriptive statistics that extended over 16 consecutive lessons in the one class and 17 consecutive lessons in the other. Observe whole-class discussion and discussed students' work with them during seatwork. The lessons were video-recorded with displays from projection technologies in the field of view. Copies of handouts to students and assessment tasks were collected and students' assessment script were photocopied. Made field notes in class and during informal interviews with the teachers after lessons, when discussion the conduct of the lessons.
教學單元	□數與運算(Number & Operations) □代數(Algebra) □幾何(Geometry) □測量(Measurement) ■資料分析與機率(Data Analysis & Probability)
教學主題	Box plots
教育階段	□國小 □國中■高中 Year 12
融入教學之工具	Graphics calculator、the Minitool 2 Java applet、sampling software
學習活動 (Learning activity)	教學策略：
	1. A homework exercise was set at the end of the class's first lesson on statistics. The lesson had been given over to : brainstorming the meaning of "statistics", generating data by playing a game, and displaying the data on a stem-and-leaf diagram. The homework was on a worksheet and students were to: draw dot plots for given datasets, partition the points on each plot into four equal groups, and determine summary statistics using a graphics calculator. The worksheet gave an example of what was expected, axes for the plots, and instructions for operating the HP39G calculator. The class had calculated median and quartile values for listed data and constructed box plots by hand in Year 10 but had not previously produced statistics or box plots on their calculators. 2. Next lesson, the teacher led discussion on ways to display data. As part Autograph to generate the dot plot for one of the homework datasets, projected it onto the whiteboard, and quizzed students on the by-hand construction of the box plot for the data. She requested the median and quartile values that students had calculated for homework, circled four groups of data on the dot plot, and spoke about the correspondences between the median, quartiles and boundaries of the grouped data. She constructed the box plot for the dataset, next to dot plot, naming and labeling the statistics during the construction. 3. The class drew the box plots for the homework datasets, on the number lines on their worksheets. 4. The teacher generated the box plots on Autograph, together with dot plots of data, projected them onto the white board, and led discussion on

	them. This brought the class's second lesson on statistics to a close. 5. The teacher led the class in producing box plots on their graphics calculators. Which one student's calculator linked to the view screen. 6. Students created data sets with a mean of 8, and calculated the median and interquartile range for several of the sets, which was the context for revising quartile calculations for any number of data. 7. Students investigated transformation effects using box plots, for homework. A worksheet gave directions to operate on data (+,-, x), calculate summary statistics, draw box plots for data before and after transformation, and gerenalise the result. Scales and instructions for operating on datasets on the graphics calculator were provided on the worksheet. 8.Un class, the teacher projected the homework worksheet onto the white board from her computer, asked the class about the transformatons, drew box plots on the projected display to illustrate answers, and led class discussion on them. 9. Texbook exercises on box plots were set but they were not discussed in class. 10. An assessment test on statistics had one question that tested understanding of box plots. It asked students to compare the weights of free range eggs and eggs from caged chickens, with respect to central tendency and dispersion. The weight information in grams was shown on two box plots. ＊Overview of instruction Teacher students introduced students to box plots by specifying how to construct them by hand from summary statistics, and students drew box plots for listed data. Later in teaching the unit of work, the teacher implemented interpretation activities and graphics calculators were used in one of these. The teacher led the class through producing box plots on their calculators. The teacher projected the display of an HP39G calculator emulator from a lap top, and this setup allowed him to point to the keys on the calculator through which the graphing was achieved. Then, he asked the class to explain the shape of the plots, both of which had missing "whiskers". The missing :whiskers" attracted the class's attention and, in discussing them, some students moved back and forth between the graph and table screens on their calculators.
所收集之 研究資料	Video、field-notes、assessment-script data.
研究結果	Ambiguity in conversation was reduced when the students and teacher pointed to the displays so others could see what they were talking about.
科技工具之特點	1. Autograph plots were more precise than is possible for hand-drawn graphs on the board something that may have assisted interpretation. 2. Technologies which display dot plots and corresponding box plots would support such analysis. Having the plots together affords students the opportunity to notice patterns in data and relate these to the box plot structure, or they can conjecture patterns in data to match the box plot structure and check their conjectures against the dot plot. 3. With Autograph, the box plot the appears above dot plot; with Minitool 2, bars partition data on a dot plot into four equal sized groups, and a box plot can be superimposed on the plot in the revised version of the applet. The dot can be removed on both Autograph and Minitool 2, leaving only the box plots. 4. The software have comparable capabilities. Multiple same-sized samples can be displayed on a single screen to allow comparison.

編號:1911

Data Extraction Form	
欄位名稱	內容
文獻來源	Kordaki, M., & Balomenou, A. (2006), Challenging students to view the concept of area in triangles in a broad context: Exploiting the features of Cabri-II, International Journal of Computers for Mathematical Learning, 11(1), 99-135.
研究目的	This study focuses on students' conceptions and their evolution concerning the concepts of area and perimeter in triangles while interacting with the Cabri-tools described in the previous section. Student conceptions were expressed through their strategies in solving the problems of construction of pairs of equivalent triangles and of performing sequences of transformations (in terms of modifications) of an original triangle into other equivalent ones.
研究問題	Our main hypothesis claimed the possibility of the enhancement of student knowledge of a learning concept by using a rich set of relevant tools provided by Cabri while performing appropriately-designed learning activities.
研究方法	This research is a qualitative study focusing on the variety of interactions realized by students working with Cabri tools as well as on the different ways that these students approached the conservation of area in triangles using these tools.
教學單元	□數與運算(Number & Operations) □代數(Algebra) ■幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	geometrical concepts
教育階段	□國小 ■國中 □高中 Secondary school：eight 1st grade students (13-years-old), nine 2nd grade students (14-years-old) and eight 3rd grade students (15-years-old).
融入教學之工具	Cabri-Geometry software
學習活動 (Learning activity)	教學策略:
	Two tasks were assigned, 1. The first being (a) to "construct pairs of equivalent triangles, in as many ways as possible" using Cabri tools (at this point, students were informed, by the researcher, that equivalent triangles are triangles with equal areas), (b) to "justify your solution strategy" and (c) to explain "what you think about the relation of the area and perimeter of these triangles". When the students seemed to be on the point of giving up, the researcher intervened, involving them in the task and encouraging them to continue by asking: "try another way of constructing another pair of triangles with equal areas. You can use other tools and the different kinds of knowledge you possess". Students worked in groups of three to perform this task, so as to exploit the advantages of cooperation. The learning aims of this task were to enable students to (i) advance smoothly from the notion of congruent triangles to the notion of equivalent triangles, beginning with the expression of their previous knowledge regarding congruent triangles and then enhancing their knowledge by exploring the equivalence in triangles using the ' 'drag mode'' operation, (ii) distinguish the concepts of area and perimeter in triangles by studying these concepts in relation to each other, and (iii) link different kinds of knowledge about the concept of area through using the diversity of the tools provided, at the same time developing a broad view of this concept. 2. In the second task, students were asked to "construct a triangle and to perform any possible sequence of modifications to produce other

	triangles equivalent to the original''. More specifically, students were asked to (a) ''construct an original triangle, then modify it into another equivalent triangle, using the Cabri tools'', (b) ''justify your solution strategy'' and (c) ''consider the produced triangle as the original triangle and repeat (a) and (b) as many times as you can, using different ways of modification''. The researcher intervened by encouraging the students to continue, as before. Students worked individually while performing the second task and it was decided to investigate how each individual student had perceived the learning experience of the first task after participating in the aforementioned group activity. The additional learning aims of the second task were to enable each individual student to (i) construct individual approaches to the concepts of area and perimeter in triangles, (ii) integrate different pieces of knowledge they possessed regarding the concept of area, by combining different strategies regarding the modification of a triangle into other triangles with equal area, (iii) to develop a broad view of the concept of area and its invariance by constructing a class of triangles equivalent to an original triangle through a sequential process of modification.
所收集之 研究資料	Data resources in this study include the electronic files of students' visual geometrical constructions, the video recordings of all interactions performed and the field notes of one of the researchers.
研究結果	The results of both tasks are presented in terms of (a) categories of strategies (b) strategies across categories and (c) group strategies across grades ＊Task 1: Constructions of Pairs of Equivalent Triangles Performed by the Students ''in as Many Ways as Possible'' using Cabri- Geometry II Tools. (a) Categories of Group Strategies：10 categories Using the ''eye''、 Preserving lengths or lengths and angles of the original triangle 、Using Cabri-commands for geometrical transformations、Splitting polygons、Forming geometrical constructions producing pairs of congruent triangles、Using the ''drag'' mode in combination with automatic area measurement、Conserving the length of the base and its distance from its opposite vertex in a triangle、Splitting a triangle using a median、Measuring areas using area-units、Using area formulae. (b) Group Strategies across Categories All groups performed strategies leading to the construction of both congruent and equivalent but not exclusively congruent triangles. The most common group strategies for the construction of congruent triangles were based on the use of isometries while those for equivalent but not exclusively congruent triangles were constructed through experimenting with the ''drag mode'' operation. ＊Task 2: Sequences of Modifications of an Original Triangle Performed by Students using Cabri-tools. (a) Categories of Student Strategies Transforming an original triangle into other, equivalent ones by splitting polygons. (b) Student Strategies across Categories The most common strategies that students performed were (a) isometries: almost all students performed more than one different strategy in this category, while the students' first, second and third transformation strategies mainly fall into this category, (b) almost all students also performed strategies which lead to the construction of noncongruent but equivalent triangles through dynamic transformations based on the use of the ''drag mode'' operation in combination with the display of area,(c) a considerable number of students (16 out of 25 students) performed

	strategies leading to equivalent but non-congruent triangles, where area formulae and area measurement using area-units were combined with the ”drag mode’’ operation.
科技工具之特點	1. All students were attracted by the ‘‘drag mode’’ operation and experimented with it in combination with the display of area. By using these features, all students constructed an abundance of equivalent but non-congruent triangles, at the same time recognizing that the area of a triangle can be conserved despite the fact that its figure can be altered. Some students also progressed in their understanding of the concept of area and its invariance by using the ‘‘drag mode’’ operation dynamically to construct families of equivalent triangles with common bases and equal altitudes.The ‘‘drag mode’’ provided by Cabri in combination with display of area and display of perimeter, students were helped to progress from the notion of congruence to the notion of equivalence and could primarily discriminate between the concepts of area and perimeter. Students also developed new modes of justification for their strategies, based on the use of these tools. (c) representations of area: numerical and visual, and (d) linking representations of area: by exploiting the Cabri capability for continuous transformations. 2. Students enhanced their knowledge of area formulae in triangles by observing visual dynamic representations in a large number of triangles with common bases and equal altitudes; these students appeared to link conservation of area with area formulae. In addition, some students proceeded to construct equivalent triangles by using area measurement in terms of area-units with the use of grid in combination with the use of the ‘‘drag mode’’ operation. In this way, conservation of area was connected with area measurement using area-units. Equivalent triangles were also constructed by splitting a scalene triangle using a median. By dynamically altering the figure of a triangle using the ‘‘drag mode’’ operation, provided as a basic option by Cabri, and automatically measuring its area, students had the opportunity to investigate the invariance of area in a large number of equivalent triangles of different figures and to move from the notion of congruence to the notion of equivalence in triangles. 3. Giving a variety of meanings to the area of a triangle using different measurement representation systems：Students had the opportunity to give a variety of meanings to the concept of area in triangles by studying its conservation in the context of different measurement representation systems, such as (a) the automatic area measurement system, where areas are represented as numbers, (b) the area-unit measurement system, where visual representations of area are produced using the provided grid and (c) the symbolic representation system of area-formulae, where areas are represented in terms of their basic linear elements. 4.In the Cabri environment, its dynamic character and the automatic measurement tools provided as well as its capability for continuous modifications makes it a powerful environment for both the teaching and learning of the concept of area in triangles as well as the study of this concept in relation to the perimeter of these shapes.

編號:1944

Data Extraction Form	
欄位名稱	內容
文獻來源	Hurme, T., & Jarvela, S. (2005). Students' Activity in Computer-Supported Collaborative Problem Solving in Math-ematics. International Journal of Computers for Math-ematical Learning ,10(1), 49-73.
研究目的	The aim of this study was to consider the applicability of the networked learning environment to mathematics learning. A secondary aim was to examine the metacognitive processes used in computer-supported collaborative learning projects in mathematics.
研究問題	
研究方法	The network-based learning environment Knowledge Forum (KF) was used to support students' collaborative problem solving. The data consist of 188 posted computer notes, portfolio material such as notebooks, and observations. The computer notes were analysed through three stages of qualitative content analysis. The three stages were content analysis of computer notes in mathematical problem solving, content analysis of mathematical problem solving activity and content analysis of the students' metacognitive activity.
教學單元	□數與運算(Number & Operations) □代數(Algebra) ■幾何(Geometry) □測量(Measurement) ■資料分析與機率(Data Analysis & Probability)
教學主題	幾何與機率
教育階段	□國小 ■國中 □高中 13-year-old Finnish secondary school students (N = 16)
融入教學之工具	The network-based learning environment Knowledge Forum (KF): The KF is a second-generation Computer-supported Intentional Learning Environment (CSILE) product.
學習活動 (Learning activity)	教學策略: Computer-supported collaborative learning (CSCL) 1. In the Geometry project, KF was used primarily as a discursive tool and in Probability it was used to support the students' inquiry process. In the lessons the students were given a task or a problem by the teacher, and were encouraged to use KF and make their thinking as visible as possible, comment on each other's notes and develop alternative solutions into discussions. The networked discussions were asynchronous, and this gave the students time to think. 2. Geometry project The Geometry project was divided into three different phases. In the first phase, Geometry 1 (three lessons), the students were given an inquiry task about a polygon, which they investigated using the KF database. They were asked to find a definition, formulas for counting the area and perimeter, and to create at least one example or problem. Students worked in pairs and had some prior knowledge of polygons. There were eight polygon inquiry tasks in total, and the products of the inquiries were posted as computer notes on the KF database. The students were asked to post comments on the content of the inquiry notes. They were particularly encouraged to discuss alternative ways of solving a problem and the correctness of an example and to ask for help for their inquiry task. The second phase, Geometry 2 (four lessons), of the Geometry project concerned geometric construction problems. This was a new topic for the students, so the teacher began by explaining the method used to solve these problems. The students went on to solve 15 geometric construction problems (created by the teacher). The students were also given paper copies of the problems and worked as individuals using a

	pair of dividers, a ruler, and paper and pencil to solve them. They were encouraged to utilise KF to elaborate their problem solving processes by composing notes to ask for help while working, or to provide explanations and alternative solutions for the given problems. During the last two lessons, Geometry 3, the students invented their own geometric problems and posted them as notes to KF. 3. Probability project The Probability course was taught over 16 lessons, in five of which the students worked with KF. The other lessons consisted of classroom instruction and exercises. In the Probability project the students worked in pairs. Two or three pairs formed a group, which specialized in one of the following topics: lottery, marbles and rolling dice. This "expert-like" method was chosen to give students the opportunity to focus on one content area and so be more specific in their networked argumentation and discussions. The teacher gave the student pairs one of the topics, such as chances to win in the lottery, picking up the marbles or rolling dice for an inquiry. The inquiry process consisted of planning the investigation, performing the experiment, and composing a final report. The networked learning environment was used to enable the discussion between the pairs about their probability inquiry.
所收集之 研究資料	＊In the Geometry project the data consist of students' posted computer notes in networked discussions, portfolio materials such as notebooks, and observation. The notebooks included students' own solutions to geometric construction problems. Observations were used to augment the researcher's interpretations of the students' networked discussions. ＊In the Probability project the data consist of the students' computer notes, including their investigation plans and final reports, and observations. The data were collected in order to examine the content of networked discussions and to analyse the students' metacognitive activity in computer-supported mathematical problem solving
研究結果	The results of the content analysis of the students' metacognitive activity revealed that the students use metacognitive knowledge and make metacognitive judgments and perform monitoring during networked discussions. 1. The quality of students' computer notes. The results of content analysis of the students' networked discussions vary between the Geometry 1, Geometry 2 and Probability projects. The majority of the notes (65%) were identified as mathematical knowledge, mathematical question and relevant note. During the projects, there were only 17 questions concerning mathematics and 33 relevant notes. 2. The results of mathematical problem solving activity. In Geometry projects KF was used more as a discursive tool. The students were encouraged to use networked learning environment to make comments to each other's notes and explain their thinking. In Geometry 1, the students discussed the problematic features of their inquiry task notes. In Geometry 2, the students had to solve geometric construction problems and provide solution methods. In the Probability project KF was used to support the students' inquiry and they worked with a problem of calculating the probability. 3. Students' metacognitive activity during networked discussions: The findings of the qualitative content analysis of computer notes describe the students' networked interaction during the projects. The students shared mathematical knowledge and questions (although there were some trivial notes). The students regulated their peers' completed notes and ongoing problem solving processes by providing alternative solutions. Furthermore, some metacognitive activity was made visible by students whose computer notes referred explicitly to either the task performed or to the networked discussion.

科技工具之特點	1. The appropriate domain-specific graphical representation tools could promote the construction of shared knowledge. That is to say, the use of symbolic language should be more supported by the technological infrastructure in CSCLin mathematics. 2. The students brought their knowledge of mathematical concepts, strategies and heuristics, into socially shared discussions in KF. To sum up the results, it seems that the instructions given to students have played an essential role in the projects. The students intended to use networked technology as they were encouraged to: they commented each other's notes (e.g., Geometry 1), provided alternative solutions (Geometry 2) and supported each other's inquiry project (Probability). The results of the qualitative data analysis indicate that utilising networked technology provides opportunities for students to use mathematical concepts and explain their solutions.

編號:1959

<table>
<tr><td colspan="2">Data Extraction Form</td></tr>
<tr><td>欄位名稱</td><td>內容</td></tr>
<tr><td>文獻來源</td><td>Tabach, M., & Friedlander, A. (2008). Understanding Equivalence of Symbolic Expressions in a Spreadsheet-Based Environment. International Journal of Computers for Mathematical Learning, 13 (1), 27-46.</td></tr>
<tr><td>研究目的</td><td>The overall purpose of this paper is to consider the conceptual aspects of learning a transformational skill (use of the distributive law to produce equivalent algebraic expressions) in a learning sequence composed of both spreadsheets and paper-and-pencil activities. This study is part of a longitudinal research study that investigates learning processes of beginning algebra (13-year-old) students. The overall purpose of this paper is to consider he conceptual aspects of learning a transformational skill (use of the distributive law to transform algebraic expressions) in a learning sequence composed of both spreadsheets and paper-and-pencil activities.</td></tr>
<tr><td>研究問題</td><td></td></tr>
<tr><td>研究方法</td><td>We conducted a sequence of classroom activities in several classes, and analyzed the students' work on a spreadsheet activity and on an assessment activity by both qualitative and quantitative methods. This study are part of the Compu-Math curriculum project for middle school mathematics. This project is based on a learning environment characterized by rich social interactions supporting high-level discursive activities, and by the extensive use of multi-representational computer software. The Compu-Math students usually work in small groups on open-ended activities that are conducted in several phases: an introductory classroom forum, work in small groups, and a whole-class summary discussion. About a third of the learning time is spent in a computer laboratory</td></tr>
<tr><td>教學單元</td><td>□數與運算(Number & Operations)
■代數(Algebra)
□幾何(Geometry)
□測量(Measurement)
□資料分析與機率(Data Analysis & Probability)</td></tr>
<tr><td>教學主題</td><td>方程式</td></tr>
<tr><td>教育階段</td><td>□國小 ■國中 □高中
The middle school mathematics The same learning sequence was given for two consecutive years to six classes of seventh grade algebra students.</td></tr>
<tr><td>融入教學之工具</td><td>Spreadsheets: Rich social interactions supporting high-level discursive activities, and by the extensive use of multi-representational computer software.</td></tr>
<tr><td rowspan="2">學習活動 (Learning activity)</td><td>教學策略:</td></tr>
<tr><td>＊The Compu-Math students usually work in small groups on
open-ended activities that are conducted in several phases: an introductory classroom forum, work in small groups, and a whole-class summary discussion. About a third of the learning time is spent in a computer laboratory.
＊A learning sequence of six class periods, which included a spreadsheet-based activity called Identical Columns, followed by short paper-and-pencil exercises, and an assessment activity called Return of the Identical Columns. The sequence, which related to the symbolic aspects of the distributive law, was conducted as part of the regular work, around the middle of the first year of a beginning Algebra course. The design of the sequence was influenced by the following considerations：
• Up to this learning sequence, Compu-Math students worked in a combined spreadsheet and paper-and-pencil environment, on about ten</td></tr>
</table>

	generational activities, based on geometric or numerical patterns of quantitative variations. Throughout their work, the students used in parallel two notation systems: the standard algebraic notation and the spreadsheet (Excel) format Thus, at this stage, the students are familiar with both the concept and the syntax of spreadsheet formulas and regular symbolic expressions. • The first spreadsheet-based activity in the sequence was included as a transition between the familiar generational activities and the paper-and-pencil, symbolic transformational activities. The combined symbolic and numerical representations inherent in the spreadsheet environment of the first activity were also intended to evoke students' global/meta-level activities, such as predicting, generalizing, or justifying, and thus to strengthen the conceptual aspects of the transformational skills learned. The other activities that followed were transformational in nature; they focused on symbolical representation and were performed in a paper-and-pencil environment. By the end of the sequence, a final assessment activity was administered to the students. ＊The Spreadsheet Activity—Identical Columns The work on this activity was in pairs, in a computer laboratory. In the first task, the students were required to fill in spreadsheet Columns A and B with two given sets of numbers arranged in arithmetical sequences. The choice of arithmetical sequences was not inherent to the task, but since the students were familiar with this feature, they were offered the option of filling in the spreadsheet table by using formulas, rather than by introducing discrete numbers. Next, the students were asked to construct in Column C, the sum of the corresponding numbers given in Columns A and B (A + B), and then to construct in Column D the sum 2A + 2B. Thereafter, the students were asked to use Columns A, B, or C in order to create two other columns of their own that are identical to Column D. The purpose of this task was to stress the symbolic equivalence between the expressions 2A + 2B and 2(A + B)—i.e., the symbolic representation of the distributive law. The expected spreadsheet formulas were 2(A + B), A + A + B + B, A + B + C, or 2C. The request to create two (rather than just one) columns was intended to encourage students to think about general relationships, rather than look for idiosyncratic numerical connections. In the second task of this activity, students were asked to write in Column G the formula 10(A + B) and again, to use Columns A and B in order to create two columns of their own that are identical to G. The expected spreadsheet formulas for this task were 10A + 10B, or (A + B)10. Note that the two tasks required the consideration of the distributive law, in different ways, by factoring out or by expanding an algebraic expression. The use of spreadsheets in this activity was intended to provide students with numerical support for symbolic transformations, to enable them to produce their own expressions, and to test their hypotheses using the resulting numbers. In these tasks, obtaining identical number columns indicates the equivalence of symbolic expressions, whereas a mismatch indicates the need for additional adaptations of the employed formula. ＊Paper-and-Pencil Exercises During the following three lessons, the students were given transformational tasks, based on the distributive law, which were presented in a symbolic representation (for example, expanding the expression 3(x + 5) or factoring out the expression 4x - 12). ＊The Assessment Activity—Return of the Identical Columns The spreadsheet-based and the assessment activities were similar in structure. The assessment activity was given in a paper-and-pencil environment. Students worked on it individually; they were required to construct two identical columns (i.e., two equivalent expressions) for 2(A

	+ B) and two other (equivalent) expressions for -2(A - B). Compared to the spreadsheet activity, this activity was more transformational in its nature—the numbers involved were likely to be treated less intuitively, the students were expected to demonstrate transformational skills, and the results were not supported by the spreadsheets' numerical feedback. ＊Teaching Sequence The teaching in all classes followed a similar sequence: The spreadsheet-based activity (90 min): In the introductory phase, the teacher presented on the board a set of given numbers, in Column A, of a simulated spreadsheet table. These numbers were substituted in the expression 2A, and the results were written in Column B. Next, the teacher asked the students to find other expressions that will produce number columns identical to Column B. Some expressions suggested by the students were correct (e.g., A + A or A 0:5) and others were incorrect (e.g., 1 + A). Next, the students worked in pairs on the spreadsheet-based activity. The teacher moved between the pairs, and helped them in their work. In the summary phase, the teacher led a class discussion on student strategies, on the concept of symbolic identity and equivalent expressions. Paper-and-pencil exercises (135 min): During the next three lessons, the students worked on expanding and factoring out symbolic expressions, by using the distributive law in a symbolic representation. The assessment activity (about 45 min): Finally, the students were given an assessment activity, similar to the initial spreadsheet-based activity. The purpose of this activity was to assess students' ability to apply, in a meaningful way, symbolic aspects of the distributive law, in a paper-and-pencil environment.
所收集之 研究資料	The data collected from 136 students included (1) 41 Excel files of 74 students who worked (most of them in pairs) on the spreadsheet-based activity. (2) Audio-taped work of four randomly selected pairs of students on the spreadsheet activity. (3) The individual work of 136 students on the assessment activity.
研究結果	1. Use of spreadsheets allows students to implement an operative and intuitive aspect of symbolic equivalence. 2. Students tend to consider spreadsheet activities as generational. 3. The learning sequence allowed students to approach a basic symbolic concept using a variety of learning trajectories. 4. Spreadsheets serve as a validating tool. 5. The learning sequence, based on both spreadsheets and paper-and-pencil, allowed for a gradual transition from generational to transformational activities 6. The characteristics of spreadsheet-based feedback pose some pedagogical and cognitive concerns.
科技工具之特點	1. Work in a spreadsheet environment enables students to employ symbolic expressions (Excel formulas) as tools that produce numerical sequences. This feature strengthens the numerical meaning of symbolic expressions in general and their equivalence in particular. Moreover, it makes the task of finding equivalent expressions more meaningful; thus, it increases student involvement in an otherwise abstract symbolical task. 2. It created a laboratory environment by allowing students to test and validate their solutions.

編號:2333

Data Extraction Form	
欄位名稱	內容
文獻來源	Koklu, O., & Topcu, A. (2012). Effect of Cabri-assisted instruction on secondary school students' misconceptions about graphs of quadratic functions. International Journal of Mathematical Education in Science and Technology, 43(8), 999-1011.
研究目的	This study investigates the effect of Cabri-assisted instruction on the misconceptions among secondary school students.
研究問題	1. What is the relationship between Cabri-assisted instruction and misconceptions of graphs of quadratic functions at the secondary school level? 2. What is the relationship between Cabri-assisted instruction and achievement related to graphs of quadratic functions at the secondary school level?
研究方法	A quasi experimental research was designed.
教學單元	□數與運算(Number & Operations) ■代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	The topics that students had studied in the previous unit were the existence of real roots and the number of roots (no real root, one and two different roots) of quadratic equations; generating quadratic equation using roots; and quadratic inequalities
教育階段	□國小 □國中 ■高中 44 tenth grade students at an urban public secondary school
融入教學之工具	Dynamic geometry software: Cabri software
學習活動 (Learning activity)	教學策略: ＊The treatment group received Cabri-assisted instruction, and the control group received traditional instruction. ＊Students in the experimental group were given four additional lessons on how to use Cabri tools and menus, specifically how to draw a graph of a line, analyse its points on a coordinate plane, and use the 'dragging' feature. ＊In the control group： following traditional means of instruction, the lessons included lectures, practice using rules and theorems on well-chosen problems, discussions of formulae and summarizing what was learned. In the experimental group：a similar lesson included Cabri-assisted instruction; in other words, the teacher used the Cabri environment on a white board while lecturing, practicing and discussing. In addition, the students had opportunities to use the Cabri environment in the laboratory. The practice problems were the same as those for the control group.
所收集之研究資料	The data analysis was conducted in two stages: First, students' previous exam scores, MS scores and achievement scores for the two groups were descriptively compared. Second, since a combination of variables usually results in a more accurate prediction than any single variable, a regression analysis, chosen for its versatility and precision, was conducted using the Enter method for the MS and achievement scores.
研究結果	The results indicate that Cabri-assisted instruction did not have a statistically significant effect on their misconceptions, but the misconception scores of the experimental group were better than those of the control group. Also, there was a significant difference between the achievement scores of the two groups. Scores of the experimental group on a quadratic functions test were significantly higher than those of the control group. The treatment group's achievement scores on the quadratic

	functions test are significantly higher than those of the control group.
科技工具之特點	High level of support for visualization is one of the Cabri's leading advantages, which helps students to understand the mathematical concepts. Thanks to the 'dragging shapes' property, students can discover how the entire construction changes dynamically. In this way, Cabri might provide a model of meaningful relationships that are not specified by symbols or represented by graphs. Visualization in geometry is a necessity for enhanced learning outcomes.

編號:2615

Data Extraction Form	
欄位名稱	內容
文獻來源	Leng, N. W. (2011). Using an advanced graphing calculator in the teaching and learning of calculus. International Journal of Mathematical Education in Science and Technology, 42(7), 925-938.
研究目的	The purpose of this study was to investigate how the use of TI-NspireTM, an advanced graphing calculator from Texas Instruments, could enhance teaching and learning of calculus.
研究問題	
研究方法	The design and conduct of a TINspire TM intervention programme for a class of 35 Secondary Four students (15–16 years) from a school in Singapore. Use of TI-NspireTM was integrated into the teaching and learning of calculus concepts with the aid of TI-NspireTM Navigator, a wireless classroom network system which connects students' TI-NspireTM handhelds equipped with a wireless cradle to the teacher's computer and projector. It facilitates transfer of documents among the teacher and learners and allows the teacher to capture students' handheld screen images to ensure everyone is on task, and collect and analyse student work to assess student understanding. This study employed a design experiment methodology that involved the preparation, design, implementation and retrospective analysis of a teaching experiment. A design experiment is an iterative process that features cycles of invention and revision. The participating teacher worked in close partnership with the author to incorporate the use of TI-NspireTM in lessons, examining the strengths and limitations of existing pedagogy and practice and acknowledging areas for future development with the TI-NspireTM technology.
教學單元	□數與運算(Number & Operations) ■代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	Calculus concepts: The topics covered were Differentiation by First Principles, Equations of the Tangent and the Normal, Rate of Change, Stationary Points, Derivatives of Trigonometric Functions, Derivatives of Exponential and Logarithmic Functions, Integrations and Indefinite Integrals, Definite Integrals, Integration of Trigonometric Functions, Integration of Exponential Functions and 1/x, and Area of a Region.
教育階段	□國小 ■國中 □高中 A class of 35 Secondary Four students (15–16 years) 35 fourth year students from a secondary school
融入教學之工具	TI-NspireTM Navigator
學習活動 (Learning activity)	教學策略:
	＊The TI-NspireTM learning activities in the intervention programme can be broadly classified into two categories. 1. In the first category, the activities focused on introducing mathematical concepts through exploration using TI-NspireTM. Students were encouraged to first examine the setting of a given problem or manipulate the parameters of a simulation in a TI-NspireTM document that was pre-loaded onto their handhelds. They were asked to formulate conjectures and examine and confirm those conjectures, culminating in the derivation of a formula, the generalization of the results or the summarization of the underlying concepts. A worksheet was designed to accompany these activities to facilitate guided discovery and inquiry learning 2. In the second category, the students were assigned tasks to reinforce

	their conceptual understanding using TI-NspireTM. In a typical activity, an exercise consisting of problems related to the concept being taught was assigned and a preprepared TI-NspireTM document sent to the students, who were required to complete the exercise with the aid of TI-NspireTM.
所收集之 研究資料	Qualitative data were collected in the form of classroom observations, self-reflections and interviews. Observation, taking of field notes and video recording were carried out during each lesson. Students were also asked to write down their reflections on a reflection form designed by the author to determine which features of TI-NspireTM they had used and the difficulties that they had encountered in using TI-NspireTM.
研究結果	Overall, the findings of the study indicate that TI-NspireTM is an effective tool to develop mathematical concepts and promote learning and problem solving. ＊Students' verbal responses (1) Master the use of TI-NspireTM, which in turn helped them to learn calculus concepts. (2) Better visualize problems and calculus concepts; (3) Connect graphical and algebraic representations of calculus concepts; (4) Identify the application of calculus concepts from simulations designed in TI-NspireTM and employ an alternative problem solving tool using a graphical method. ＊Analysis of the interviews with the eight students revealed several indings. (1) The dominant conceptual understanding of the derivative at a point was that it is the gradient of the tangent line at the point. (2) Students were able to use the algebraic and graphical methods to solve derivative problems. (3) Students were able to connect their conceptual understanding of the derivative concept with numerical and algebraic representations. (4) Students were not able to use a symbolic definition of the derivative at a point that involved the concept of limits. (5) The dominant approach to solving derivative problems was the algebraic method. (6) Most of the students were unable to make a connection between their understanding of the derivative and the instantaneous rate of change. ＊The students used TI-NspireTM as a tool in several different ways. Six ways of using TI-NspireTM as a tool in the mathematics classroom were identified in this study. In the intervention programme, TI-NspireTM was used as an exploratory tool, graphing tool, confirmatory tool, problem-solving tool, visualization tool and calculation tool.
科技工具之特點	1. TI-NspireTM gave the students the means not only to explore the concepts of calculus, but also to communicate those concepts mathematically. With the use of TI-NspireTM Navigator wireless network in the classroom, the students were able to present their solutions and to provide feedback to the participating teacher during the lesson. The TI-NspireTM Navigator, which creates a wireless network in the classroom, promoted communication in the learning process, and hence supported the classroom learning community. The use of TI-NspireTM Navigator in the classroom also raised the level of participation of the students during the lessons and strengthened their commitment to the learning process. 2. The visual and numerical representations of the derivative at a point on TI-NspireTM helped the students to develop their conceptual understanding.The students were able to form connections between the different representations of the derivative in calculus using TI-NspireTM,

	which helped them to develop a conceptual understanding of the derivative. The use of a graphing calculator can change the teaching and learning of calculus concepts from relying solely on algebraic method to encompassing numeric, algebraic and graphical methods. The graphing calculator provides a better connection between algebraic and graphical representations.

編號:2772

Data Extraction Form	
欄位名稱	內容
文獻來源	Song, K. S. and W. Y. Lee. 2002. A virtual reality application for geometry classes. Journal of Computer Assisted Learning, 18 (2), 149-156.
研究目的	This paper describes the use of the Virtual Reality Modelling Language (VRML) to visualise 3-D objects for middle school geometry classes in a networked environment and shows its usefulness for both teacher and students.
研究問題	
研究方法	A comparison of the test results from VRML-based geometry classes and traditional classes, that solely depend on verbal explanation with paper and pencil.Two groups of classes were created; one using networked VRML materials, and the other taught in the conventional way.
教學單元	□數與運算(Number & Operations) □代數(Algebra) ■幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	Three main geometric topics: Oservation of plane figures, the properties of plane figures and observation of solid figures.
教育階段	■國小 □國中 □高中 The 6th grade Korean
融入教學之工具	Virtual reality
學習活動 (Learning activity)	教學策略:
	1. To introduce the concept of 'a point is not sufficient to define a plane', the teacher uses the VRML object. If the teacher clicks on the point with the mouse, three planes appear and cross that point 2. After the three planes have appeared, the teacher explains the following: 'when any plane crosses a point in any direction, it is not sufficient to compose a plane with a point.' 3. The teacher can manage the three VRML planes on the computer screen and can explain the situation repeatedly. The planes can be displayed repeatedly by controlling buttons, the dynamic images gather attention from the students and increase their active participation in the class. It is frequently reported that students get bored very easily with given courseware due to the lack of variety. Providing VRML objects as class support material to imitate 'physical reality' as 'virtual reality' allows both teachers and students can share ideas and their understandings very actively through manipulating VRML objects. Also, the teacher can use these figures as new media to deliver axiomatic ideas. ＊The VRML group classroom was equipped with computers and audio-visual facilities. The teacher used VRML objects for scheduled teaching, and students were allowed to explore VRML objects with their computers in the third class as a way of self-study. ＊the traditional approach group students did problem solving in the third class after two teaching classes. After tutoring the subjects, both groups were tested with the same questions in the last class. The chosen method was student knowledge of taught geometry subjects.
所收集之研究資料	RML-based class was analysed by applying statistical differences of correct answer rates for given questions between the two groups.
研究結果	The application of VRML based 3-D objects has a positive effect on students' learning of geometric topics.
科技工具之特點	1. The VR application used in this study does not have such powerful dynamics of interaction with other objects, but can show geometrical objects in 3-D and allows students to explore them by rotating, moving and zooming. 2.The advantages of the VRML-based geometry classes can be summarised as follows. (1)It provides a virtual reality of figures and objects that cannot easily be

	described verbally. (2)The web application of VRML materials can be effectively used for teaching or learning purposes in class. (3)Any geometry figure can be easily modelled into VRML drawings.

編號:2797

Data Extraction Form	
欄位名稱	內容
文獻來源	C.-K. Looi &K.-S. Lim. (2009). From bar diagrams to letter-symbolic algebra: a technology-enabled bridging. J. Comp. Assisted Learning, 25(4),358-374.
研究目的	Our goal is to conduct rigorous and reflective inquiry to test and refine innovative learning environments, as well as to refine new learning design principles.
研究問題	Our research questions are: 1.does our bridging pedagogy help students to better learn letter-symbolic algebra? 2.How does the enacted bridging pedagogy help students to better learn letter-symbolic algebra? 3.How does technology (ALGEBAR) enhance the bridging pedagogy?
研究方法	
教學單元	□數與運算(Number & Operations) ■代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	The unit taught was the use of algebra to solve problems in whole numbers, fractions, ratios and percentages. The objectives were to teach the students to define an algebraic variable and to formulate the equations.
教育階段	□國小 ■國中 □高中 Secondary 1 for purposes of this research.
融入教學之工具	software tool ：AlgeBAR
學習活動 (Learning activity)	教學策略: The experimental class was taught using the software AlgeBAR for 1 h each week in the computer laboratory. The objective of the intervention was to enhance the students' ability to define variables algebraically and to formulate algebraic equations before proceeding to solve the problems. The experimental class has an hour in the computer laboratory usingAlgeBAR for the 4 weeks of intervention. A typical lesson would have the teacher demonstrate using one or two examples before the students were tasked to work in pairs on randomly generated questions. The teacher would walk around to monitor students' progress and correct their mistakes. It was observed that for ordinary problems involving whole numbers, the students were competent in using AlgeBAR to draw models and were able to define the variables and formulate the main equations. When the class moved on to problems involving fractions and ratios, students were observed to have difficulty drawing models for more difficult questions and were inevitably unable to define the variables and main equations. When students were finally able to construct the models, they somehow seemed to be in a better position to define the variables.
所收集之 研究資料	For data collection, pre- and post-intervention clinical interviews.
研究結果	The test scores for the experimental class (M = 50.35, sd = 19.77) were significantly higher than for the control class. The students' PSLE Mathematics grades, the experimental class (adjusted M = 49.93) still performed significantly better than the control class (adjusted M = 31.25) in the post-test [F(1, 65) = 19.9, P < 0.001, partial eta-squared = 0.23]. ＊Observations from pre-intervention and post-intervention clinical interviews with students: The first observation from the pre-intervention quiz and interview

	indicates that the students are familiar with the model method, especially in solving routine questions. The second observation indicates that when the problem demands more sophisticated model drawing, as in pre-intervention quiz question 2, students are unable to translate the problem into model, and thus, are unable to proceed further. Only one student was able to draw the model for this question, and it was only partially labelled too. Equipping the students with algebra will help them solve problems that do not lend themselves to model drawing easily. The third observation from post-intervention interview, and supported by the post-test, indicates that after 4 weeks of intervention, the stronger student is able to define variables and formulate equations, the average student is able to define variables and formulate equations for routine questions, but the weaker student is only able to define variables correctly. All the three students interviewed associate algebra with 'using letters to substitute for unknowns'. They have modest confidence in its use as it is a relatively new topic. They believe that algebra is a powerful tool that can help to solve problems efficiently, but they have not fully grasped its concepts. When given a problem, only the stronger student (one out of three) indicates readiness to use algebra, and the other students are likely to fall back on model method or other heuristics.
科技工具之特點	1. AlgeBAR also helps students to check for consistency in the model and equations. This checking mechanism provides scaffolds for the students, letting them know if they are on the right track. It enables the students to explore and attempt the questions with less help from the teacher. 2. AlgeBAR has benefited students in some ways. It helps students to understand the problem better and faster. This is because it facilitates model drawing, the process of which helps students to visualize the problem faster and better.

編號:2834

Data Extraction Form	
欄位名稱	內容
文獻來源	Kramarski, B., & Ritkof, R. (2002). The effects of metacognitive and emails interactions on learning graphing. Journal of Computer Assisted Learning, 18, 33–43.
研究目的	The main purpose of the study was to investigate the differential effects of the use of EXCEL software embedded with EMAIL vs. EMAIL + META interaction on students' graph interpretation and graph construction. The purpose of this study was twofold: 1. To investigate the effects of metacognition and email interaction between teacher-student on learning to interpret and construct graphs. 2. To describe the email interaction on three levels of interaction: tutorial, metacognitive and life.
研究問題	
研究方法	One class (n = 25) was exposed to EXCEL software embedded within email interaction (EMAIL) and the other class (n = 25) was exposed to EXCEL software embedded within email interaction and metacognitive instruction (EMAIL + META). Three measures were used to evaluate learning graphing: a graph interpretation test, a graph construction test and levels of interactions in emailed messages.
教學單元	□數與運算(Number & Operations) ■代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	方程式圖形推論
教育階段	□國小 ■國中 □高中 50 ninth-grade students
融入教學之工具	EXCEL software、EMAIL
學習活動 (Learning activity)	教學策略: Metacognitive instruction
	One class (n = 25) was exposed to EXCEL software embedded within email interaction (EMAIL) ；the other class (n = 25) was exposed to EXCEL software embedded within email interaction and metacognitive instruction (EMAIL + META). ＊EXCEL and email interaction: All students were exposed to learning about graphs by EXCEL software embedded within email interaction with the teacher. The main purpose was to use advanced technologies for learning. In particular, in all classrooms students studied: (a) presenting information by graphic representations and how to make decisions about the appropriate graph; (b) quantitative and qualitative methods of graph interpretation; and (c) drawing conclusions from graphs. In all classrooms the unit was taught one hour a week for seven weeks. At the beginning of the unit the teacher introduced the principles of constructing graphs with EXCEL software and strategies of graph interpretation such as using tables, algebraic formula and verbal explanations. All students in both conditions practiced graph construction and graph interpretation strategies with the same tasks, and all used the same booklets. In addition, the students were taught how to send/receive emails and how to send/open file attachments. Moreover, students were encouraged at any time to ask the teacher questions or send comments by email. ＊The metacognitive instruction used a series of four self-addressed metacognitive questions: comprehension questions, connection questions, strategic questions and reflection questions 1. The comprehension questions were designed to prompt students to

	reflect on the problem/task before solving it. In addressing a comprehension question, students had to read the problem/task, describe the concepts in their own words, and try to understand what the concepts meant. The comprehension questions guided students to interpret the graph at both the local-to-global dimension and the quantitative-to-qualitative dimension. 2. The connection questions were designed to prompt students to focus on similarities and differences between the problem/task they were working on and the problem/task or set of problems/tasks that they had already solved. The connection questions referred to questions that guided students to find similarities and differences between the graph at hand and graphs they had already interpreted, and to compare different intervals on the same graph or different representations for the same graph solution. 3. The strategic questions were designed to prompt students to consider which strategies are appropriate for solving the given problem/task and for what reasons. Strategic questions referred to strategies that students could use in interpreting the graphs which include using data-tables or to referring to the algebraic representation of the graph. 4. The reflection questions were designed to prompt students to reflect on their understanding and feelings during the solution process. The metacognitive questions were used in students' small group/individualized activities, and in writing in their booklets. In addition, the teacher modelled the use of the metacognitive questioning when she introduced the new concepts to the whole class, reviewed the materials, and helped students in their activities. Students were told that asking and answering the metacognitive questions would help them to understand the mathematics presented in the class and in life. ＊EMAIL + META condition: The students studied according to the IMPROVE method described above. For practising that method the students were asked to send the teacher by EMAIL the solution of five graph tasks, and to describe in writing the solution process. In their EMAIL interaction they were encouraged to use the metacognitive questions: comprehension questions, connection questions, strategic questions and reflection questions. They were also encouraged to ask the teacher for help when they encounter difficulties in understanding and to correct the graphs, if needed, after receiving feedback by EMAIL from the teacher. ＊The EMAIL condition: The students studied the same as under the EMAIL + META condition but they were not exposed to the metacognitive instruction. Students were asked to send the teacher the solution of five graph tasks by EMAIL and to describe the solution process in writing. They were encouraged to ask the teacher for help by email when they encountered difficulties in understanding and to correct the graphs, if needed, after receiving feedback by EMAIL. Appendix 2 presents an example of how the graph tasks were introduced in the EMAIL + META vs. EMAIL conditions.
所收集之 研究資料	Graph interpretation test、Graph construction test、Levels of interactions in emailed messages.
研究結果	Results indicated that the EMAIL + META students significantly outperformed the EMAIL students on graph interpretation and graph construction. In particular the effects were observed on students' ability to explain mathematical reasoning and on reducing misconceptions regarding graphs. Furthermore, qualitative analysis of the EMAIL messages indicated that the EMAIL + META students frequently used different levels of interaction in their email interactions than the EMAIL students.

	1. Graph interpretation It was found that the EMAIL + META students significantly outperformed the EMAIL students on graph interpretation. It significant differences between treatment groups were found at the end of the study controlling for pre-treatment differences for mathematical explanations and reducing misconceptions regarding graphing. 2. Graph construction It was found that the EMAIL + META students significantly outperformed the EMAIL students on graph construction. 3. Levels of interactions in emailed messages Qualitative analysis of the email messages indicated that more students of the EMAIL + META condition used significantly different levels of interaction than did the EMAIL students.
科技工具之特點	It seems that the EMAIL + META condition succeeded in building a mathematical community where students expressed their mathematical ideas fluently and flexibily using various levels of interactions (tutorial and metacognitive). By formulating written explanations, students learned valuable lessons about the need for accuracy, precision and completeness in their answers.

編號:2843

Data Extraction Form	
欄位名稱	內容
文獻來源	Chen, Y.-H., Looi, C.-K., Lin, C.-P., Shao, Y.-J., & Chan, T.-W. (2012). Utilizing a Collaborative Cross Number Puzzle Game to Develop the Computing Ability of Addition and Subtraction. Educational Technology & Society, 15 (1), 354–366.
研究目的	In this study, we explore a collaborative way for students to learn these skills in a technology-enabled way with wireless computers. Two classes, comprising a total of 52 students in Grade 4 (ages 10 or 11) participated in the study. This paper investigated the benefits of learning addition and subtraction through the game "Cross Number Puzzle" on Group Scribbles. Our observations and investigations of the two classes who played the game individually and collaboratively respectively showed some interesting differences.
研究問題	
研究方法	We conducted a study on two classes of students to explore different collaborative learning patterns that involved students working together on solving arithmetic problems. We also examined differences between individual learning and collaborative learning. In this research we explored the effects of "Cross number puzzle" game applied in learning, which was designed to provide the feedback mechanism. We had two experimental classes: students in Class A played the"Cross number puzzle" game in small groups, and students in Class B played the game individually The study for both classes lasted for four weeks. In the first week, a session for 30-minute pre-test and 20-minute training was executed. Students were asked to be familiarized with GS and the operation of the game with simple exercises. In the second week, the game was played in one lesson lasting for 60 minutes, followed by a 30-minute post-test and a 20-minute questionnaire in the third week. In the fourth week we interviewed the teachers and students. A pre-activity and three learning activities were included in this study.
教學單元	■數與運算(Number & Operations) □代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	Arithmetic problems : addition and subtraction
教育階段	■國小 □國中 □高中 Fifty two students in Grade 4
融入教學之工具	Scribbles software："Cross Number Puzzle" that was designed with the "feedback" mechanism to assist students' problem solving. Group Scribbles (GS) is a computer-supported collaborative learning system.
學習活動 (Learning activity)	教學策略: Computer-supported collaborative learning
	＊In one class, students played the game individually and in the other class, students played the game collaboratively. ＊Students were asked to be familiarized with GS and the operation of the game with simple exercises.In the game playing session, three tasks were designed and implemented in collaborative group (Class A) and individual group (Class B) separately. Students were asked to fill in the operator in an arithmetic equation in Activity 1. Activity 2 is about filling in the unknown number while in Activity 3, students were asked to estimate using trial-and- error methods to solve the problem. Group members could use their private boards for sketches and confirmatory calculations. Then they could post their sketches or results to the public board.
所收集之	Pre and post-tests, collected questionnaires, did ideo-recording of their

研究資料	activities in classes and tracked their screens in the process of game playing.
研究結果	1. pre-tests and post-tests This indicates students in Class A made greater progress than those students in Class B through playing the game collaboratively. Further observation of these collaborative groups suggests that the low math-achiever students made the most significant progress, which can be easily gathered from the following table. The striking result to emerge from the data is that the collaborative group had much greater improvement than the individual group in this study although they played the same game. 2. Questionnaire Students tried to do cooperation and discussion before they submitted the answer when they played the “Cross number puzzle” game. There was one high-achiever student who did not discuss with others when he did his calculations. Students claimed that it was much easier to complete the calculations with collaboration than doing them individually. Those students without confidence in mathematics found it easier to share their own ideas with others and complete the calculations together. All students agreed that they derived benefits from discussion with other classmates 3.”Tips” usage in Class A and Class B That when a student encounters problems and difficulties and in the situation where there is no help from peers, he or she would search help from the “feedback” system. On the other hand, students in Class A would discuss their strategies to solve the problem within a group first, allocating cooperative work among group members. They only referred to the “feedback” system when every student in the group was uncertain on how to proceed They used the “tips” less often then students in Class B. Students in Class B seldom initiatively asked for help from their classmates but only referred to the tips when they encountered difficulties. However either in Class A or Class B, high-achiever students seemed to have used the “tips” far less than low-achiever students. Low achieving students relied more on “tips”. 1. Learning Activity 1: Remove the operator. Four different patterns of collaborative problem solving were found in their activities of “remove the operator”: whole-group-deciding, two-member-deciding, leader-deciding and individual deciding. 2. Learning Activity 2: Fill in the figure in the formula sentence some insights of methods of students’ collaboration and their strategies to complete the calculation. (1)Individual calculation: Group members did the calculation by themselves individually. Little collaboration occurred. (2) Comparison: Started from different thread and compare each other’s result at the intersection (3) Relay: One finish one section and another take over to continue calculating (4) Assisted calculation: One of the group members is in charge of all calculation and other members checking his/her calculating process (5) Through-out calculation: Some members calculate from the beginning to the end and other members calculate from the end to the beginning then they compare at the intersection. 3. Learning Activity 3: Fill in Multi-unknown student’s working path, trace group’s problem solving strategies (1) Individual calculation：Group members did the calculation by themselves individually (2) Cross calculation：Started from different paths and compare each other’s result at the intersection

	(3) Reverse calculation：Some members calculated following vertical or horizontal paths, other members calculated from the result to get the answers. 4. video recordings of the students' activities together with the recording of computer screens, different interactive patterns in eight groups were identified: (1) Unresponsive: The leader communicates with other members but they do not respond; (2) Unsocial: There is no interaction among the group members; (3) Dominant leader: The leader communicates with group members who revere and follow the leader; (4) Tete-a-tete: Every member interacts with his/her neighbors, which may lead to emergent sub-groups; (5) Fragmented, cliquish: Fragmented interactions within individual sub-groups but no interaction at the full-group level; (6) Stilted: Each and every member interacts with his/her neighbors; the interactions have yet to reach an ideal status albeit some individuals have opportunities to interact with each others. (7) Ideal: All the group members actively interact with each others, and there are multiple communicative paths. ＊Collaboration also plays an important role in enhancing learning in Class A with the incorporation of the "feedback system" and collaboration strategies ＊The students had five methods of calculations: individual calculation, comparison, relay, assisted calculation and through-out calculation. Students also showed four different ways of calculation: free calculation, calculate from the top, calculate from the bottom and calculate from both the top and bottom. They did the calculation in three different collaborative ways: each student calculates the whole thing him/herself; one student started from the top and the other started from the bottom; and they did backwards calculation for checking
科技工具之特點	Feedback mechanism： When the students complete the calculation, they can fill in the answer box and press OK button under the question area to submit. If the answer is correct, there will be a brief description of the key points. If the answer is wrong, the system will execute a step-by-step tip based on the number of errors from the user inputs (Figure 8, a popup box with tips shown in individual area). The action repeats until the maximum number of errors reaches the upper limit. Then the system will show the correct answer and the methods of problem-solving. The "feedback" system because they could get help from group members. However, in both classes, the low-achiever students had the highest demand for "tips" for help.

編號:2996

Data Extraction Form	
欄位名稱	內容
文獻來源	Yelland, N. (2002).Creating Microworlds for exploring mathematical understandings in the early years of school. Journal of Educational Computing Research, 27(1), 77-92.
研究目的	This study explored the strategies and interactions of children in a computer based microworld related to the concept of length.
研究問題	
研究方法	Describe the strategies and interactions of pairs of Year 2 children (average age 7 years 4 months) while they worked on novel tasks in a computer microworld embedded in a mathematics curriculum. The curriculum encouraged the active exploration of ideas in both on and off computer tasks, which complemented each other. Observations of the children supported the notion that the active construction of knowledge in a computer supported collaborative learning context, enabled the children to engage with powerful ideas and use metastrategic strategies. Further their spontaneous comments and persistence with tasks indicated a high level of interest and enthusiasm for these tasks in preference to those that traditionally characterize mathematical activity.
教學單元	□數與運算(Number & Operations) □代數(Algebra) □幾何(Geometry) ■測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	concept of length
教育階段	■國小 □國中 □高中 Year 2 children (average age 7 years 4 months)
融入教學之工具	Geo Logo
學習活動 (Learning activity)	教學策略: Computer supported collaborative learning.
	＊28 children in the study who worked in pairs. 1. The sequence of tasks in How Long? How Far? The content of the unit pertains to the exploration of linear measurement and involves the processes of determining, analyzing, and comparing both arbitrary and standard units of length. 2. In the sequence of activities that were used in this study, the children first played turtle with their partner in order to experience giving commands that involved both distance and turning movements. They then completed a non-computer task that required them to find and sort items that were; about the same as, longer than and shorter than 3 strips of paper/ string that were of various lengths. 3. In the first computer based task, called Steps, the pairs of children took turns to direct their individual turtle to a randomly generated item with steps of the same size. In the next activity, Giant Steps, although their items were placed at an equal distance from each turtle, they had to use different sized steps in order to reach the item. Next there was a maze task in which the children were required to collaborate in order to take a mother turtle to her baby, located at the end of the maze. Three sizes of the steps were randomly generated and the players were shown which size was being used in any particular game. Additionally, in this activity there was a meter located at the top of the screen, which indicated how much energy, the turtle was using in order to move through the maze. If the energy level was depleted the activity was considered to be over. The final two activities of the unit were completed first off the computer and then on it. They involved directing an ant and turtle respectively around a make believe town in order to visit various locations. An integral part of the task was that the turtle had to be "recharged" at a battery stop after

	ten distance moves. If the turtle ran out of energy it could not move any distance at all.
所收集之 研究資料	The data source was rich since it included video tape of the computer screen with an insert of the children in the top right hand section so that extensive analsyses of their strategies and interactions could be made with reference to specific aspects of the task that they were in the process of solving.
研究結果	At all times the children were engaged with the ideas that were embedded in the tasks and revealed a high level of interest and enthusiasm throughout the study. It was apparent that the children were working mathematically using the ideas inherent to the concept in effective ways and indeed able to examine their actions in detail and develop skills in metastrategic thinking during their problem solving.
科技工具之特點	The microworld not only provided an important link between the real world and classroom activity, but it also afforded the opportunity to actively construct units of measure and change them in a dynamic and interactive way. Working in the microworld enabled the pairs of children to engage in critical discussions, which impacted on their understandings in various ways, and they were also able to generate hypotheses, test them out and immediately modify strategies and opinions about concepts of length.

編號:3079

Data Extraction Form	
欄位名稱	內容
文獻來源	Figueira-Sampaio, A. S., dos Santos, E. E. F., & Carrijo, G. A. (2009). A constructivist computational tool to assist in learning primary school mathematical equations. Computers & Education, 53(2), p484-492.
研究目的	The objectives of this study were (1) develop a computational tool to replace a conventional balance in practical mathematics exercises thereby solving two material challenges for Brazilian teachers: verifying the accuracy of balances and the lack of student physical and social activity through direct participation. (2) determine how substituting the conventional balance with a computational tool for the solution of first degree polynomial equations affected the aspects inherent in the learning process like motivation, cooperation, dialogue, discussion, reflection, reciprocity, negotiation and responsibility.
研究問題	
研究方法	A case study: This research is of an exploratory and descriptive character. Exploratory research helps develop a general vision with certain phenomena in perspective, with the goal of identifying relevant variables that should be considered in the research. Whereas descriptive research seeks, based on well defined objectives, to expose the characteristics of the phenomena or establish relationships between variables.
教學單元	□數與運算(Number & Operations) ■代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	Polynomial equations of the first degree
教育階段	■國小 □國中 □高中 the 6th year of a public elementary school
融入教學之工具	Computational tool
學習活動 (Learning activity)	教學策略:
	Group A was taken to the computer laboratory to use the virtual balance. Group B was taken to the mathematics laboratory to use the conventional balance. In the computer lab, two students were placed at each computer in order to analyze interpersonal skills. Because of the pedagogic–didactic principles of the school, it was not possible to have another group that only participated in the classroom but not in a laboratory In the laboratories, students were presented with five first degree polynomial equation problems of various levels of difficulty (x + 4 = 10 + 4; 5x + 1 = 35 + 1; 2x + 5 = 10 + x; 3x + 12 = 12 + 13 + 2x; 5x + 50 = 3x + 290). They were also provided with a balance and a teacher was present. In the computer laboratory, the equations were presented and solved in the computational tool. While, in the mathematics laboratory, the professor wrote the equations on the blackboard so that the students could follow the solution with the conventional balance. ＊While in the mathematics laboratory (Group B), students could not explore the balance and the objects on the balance because it needed to remain accurate for the completion of the activity. Only the teacher had direct contact with the educational activity, since there is only one balance for classes that have an average of 24 students. The teacher had to carefully manipulate objects on the balance and try not to affect the accuracy of the balance while trying to re-establish equilibrium. The students observed the equilibrium and disequilibrium of the balance and recorded what happened in their notebooks. There was a lot of unrelated conversation among the students because they were not participating

	directly in the experiment. This dialogue among students, far from being useful in terms of achieving goals, was a deviation since the students were not actually involved in the activity. This resulted in constant interruptions during the class as the teacher requested attention and silence. ＊In Group A, through socializing, each pair of students was responsible for their own learning and pace of learning. The students had to organize and manage their time to complete the activity. Using the computational tool, each pair of students solved each of the five proposed equations in different time intervals. The pairs started the activity at the same time in the computer laboratory. However, it was observed by the monitors of the computers that the pairs were solving different equations or at different stages of the same equation. Despite the fact some pairs were solving equations ahead of other pairs, all the pairs worked at the activity for the 50 min permitted for the completion of the five equations.
所收集之 研究資料	Data collection was accomplished through non-participatory observation while the students executed tasks, with the intention of identifying the possible contribution of the computational tool on the learning process. Observations of what was seen and sensed during the activities were recorded as detailed field notes. Practical classes in both the computational laboratory and the mathematical laboratory lasted 50 min.
研究結果	The student pairs utilized all the available time for an activity does not invalidate the fact that the progress in an activity was based on the students' own learning rates. Through experimentation provided by the computational tool, students began to take in what they had learned. This was observed as the students progressed through the different levels of complexity of the equations. The actions taken to solve each subsequent equation were more confident. In most cases, the discussions and questions between the students in each pair were different from those observed during the solution of the previous equation. Previously observed errors ceased to happen. In some pairs, it was also observed that after solving the first two or three equations the students were able to solve subsequent equations by means of mathematical–logical actions before manipulating the virtual objects. In Group A, it was observed that the interaction permitted by the tool and students working together in pairs at a computer brought the students together during the activity and created an environment for mediation between them encouraged by the teamwork and dual responsibility of completing the activity. Students took turns solving the equation: one student would address the disequilibrium from the right side of the balance and the other student from the left. Attempting to solve the equation alone was not observed in any of the pairs. Differences between students did not impede completion of the activity. Differences were accepted in a positive way. The students began to communicate by listening to suggestions or posing questions to their partners. Cooperative work awakened concern about the learning of others. Students with greater ability served as direct guides for less able students while solving equations and even while operating the computational tool. Faced with a misstep, it was common to hear one student asking another: "You removed "x" from the left side of the balance and now the balance is not in equilibrium", "Click here", "The balance is in disequilibrium", "The equation in the visual panel shows that we removed "weight" from the right side. What should we do now?", "The light on the balance is green. Can we continue?", "Do you want me to explain again?". ＊The results indicate that the cognitive computational tool met the challenges of Brazilian teachers. First, because it lacks mechanisms that need to be verified for accuracy in order to demonstrate equilibrium. Second, because it allows the direct participation of students (physical

	experience) and the use of the tool in small groups (social experience). The hands on completion of the activity, realistic appearance, the interaction with the tool, visual feedback on the panel, and two students using the same tool awakened motivation, responsibility for completing the activity, dialogue, cooperation, discussion and reflection. Doing the experiment with others aroused concern about the learning of others and reciprocity of knowledge for the improvement of the procedure to be constructed for solving 1st degree equations.
科技工具之特點	1. Experimentation combined with manipulation, visualization and reasoning using the computational tool to solve a real world problem allows an exchange of opinions and integration of different points of view. Since students were able to use the monitor to follow each executed action and the effect of this action in real time. Feedback in the visual panel, which shows partial results at each step of the solution of the equation, allowed the students to detect errors and reflect on the subsequent action. For each action, students reflected on and discussed the next action to be executed. They no longer solved equations through trial and error. Consequently, teaching became more dynamic. 2. Direct experimentation awakened motivation, responsibility and activity coordination. Two students using the same computer contributed to the proximity between them and awakened qualities such as communication, negotiation, cooperation, reflection, discussion and reciprocity. These aspects are identified in the constructivist theories of Piaget and Vygotsky. This lets the teacher take on the role of facilitator of mathematics education.

編號:3357

Data Extraction Form	
欄位名稱	內容
文獻來源	Harries, T., & Suggate, J. (2006). Exploring links across representations of numbers with young children. International journal for technology in mathematics education, 13(2).53-64.
研究目的	The specific purpose of this project is to use a suite of IT programmes which will allow pupils, particularly those who are having difficulty with mathematics: ・ to explore a variety of ways of representing numbers. ・ to explore ways of undertaking addition and subtraction operations. ・ to explore ways of undertaking multiplication and division operations. For the purposes of this study the emphasis is on external representations which may help pupils to develop flexible and powerful ways of working with concepts and operations
研究問題	
研究方法	Numbers can be represented in a variety of ways – through pictures, diagrams, symbols. Each representation highlights different features of the number and the number system. This study aims to explore pupil understanding of number both within and across representations. A computer environment (suite of programmes) was created within which representations could be generated and manipulated. This study focuses on one of the programmes within which activities were developed for pupils in years 1, 2 and 3 of English primary schools (ages 5 to 8 years).
教學單元	■數與運算(Number & Operations) □代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	Addition and subtraction operations、multiplication and division operations.
教育階段	■國小 □國中 □高中 Years 1, 2 and 3 of English primary schools (ages 5 to 8 years).
融入教學之工具	IT programmes: the programmes provide the opportunity for communication and discussion between pupils and between pupil and teacher about the work. Since the programme ideas make transparent the structural aspects of number work, the characteristics of different representations are highlighted and hence the role of representations as mediators for developing meaning can be developed.
學習活動 (Learning activity)	教學策略:
	The pupils were introduced individually to the programme, Number 1-99. They were first shown the representations. They were then asked to choose two representations. The researcher constructed a number in the first representation. The pupil constructed the same number in the other representation. In each case the pupil works in tens and units. This exercise was repeated twice with a different pair of representations each time, but with the pupil now constructing the number in both representations. Thus each pupil had direct experience of six representations and each time would see on the screen a pair of representations. Following this exposure to the representations and the programme itself, the pupils were shown a different number in each representation and asked to identify it. The order of the representations was randomly chosen for each pupil but the numbers used were the same each time. The pupils' answers were noted together with any relevant observation (such as, pointing, eye movement, vocalisation). The pupils were also asked how they had obtained their results. The accuracy of the

	answer was not the only focus of interest but any common errors were also noted as these might indicate where particular care is needed in teaching.
所收集之 研究資料	In the first section the analysis simply explores the results of the study using percentage scores. In the second section the analysis will be conducted in relation to a Rasch model.
研究結果	Essentially the two analyses suggest that there are five main findings: 1. Not all representations are equally well understood (the number line seems to be especially difficult particularly for low attaining pupils). Indeed there is a clear hierarchy of difficulty associated with the representations used. 2. 'Reading figures' accurately, which is a skill that virtually all pupils can accurately employ, comes before an understanding of place value. 3. Over the first three years of schooling there is a great improvement in understanding all representations except the number line and the beads. There is a substantial difference between the responses of the high attainers and the other groups – particularly in the first year. Generally the greater change is through the first year. 4. An ability to count in tens and ones is associated with greater understanding of many representations. 5. Low attainers are not only liable to make more errors but they are also more likely to offer no response.
科技工具之特點	That these representations have to be viewed as abstract conceptual frameworks through which pupils can construct understandings of number and operations and not just as illustrative mediators. The representations need to be seen as tools through which understanding can be constructed. The facility to see through the representations can help pupils to build their sense of a number and numbers in general.

編號:3505

Data Extraction Form	
欄位名稱	內容
文獻來源	Suh, J., Moyer, P. S., & Heo, H. J. (2005). Examining Technology Uses in the Classroom: Developing Fraction Sense Using Virtual Manipulative Concept Tutorials. The Journal of Interactive Online Learning, 3(4), 1-22.
研究目的	This project explored ways in which virtual manipulatives could facilitate the connection between conceptual and procedural understanding by capitalizing on the graphic/nonlinguistic features of the virtual fraction manipulatives.
研究問題	What learning characteristics are afforded by the use of the virtual fraction manipulatives for understanding fraction equivalence and addition?
研究方法	
教學單元	■數與運算(Number & Operations) □代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	Fraction equivalence and addition of fractions with unlike denominators.
教育階段	■國小 □國中 □高中 46 fifth-grade students in three classes at the same elementary school
融入教學之工具	Virtual manipulative(two virtual manipulative applets from the National Library of Virtual Manipulatives (http://matti.usu.edu/nlvm/index.html) and one applet from the NCTM electronic standards (http://nctm.org))
學習活動 (Learning activity)	教學策略: Each lesson began with an introduction to the virtual manipulative applet that would be used that day and several mathematical tasks for the students. On each day in the computer lab, students received a teacher-made task sheet that provided instructions for using the virtual manipulatives, several problems, and space to record work. These directions focused students on the mathematical tasks during the lessons. The teacher reviewed the instructions with the class and modeled how to use the virtual manipulatives before students worked independently on the activities.
所收集之研究資料	Observation field notes, student interviews, and classroom videotapes.
研究結果	The results below focus on the observations, student interviews, and videotapes of students' interactions with the virtual manipulatives during the project to determine the learning characteristics of the technology that may have supported student understanding. Task 1: Finding Equivalent Fractions 1.Discovery learning: This fraction applet features an arrow button that enables students to experiment with various visual representations of the denominator up to 99. When using this applet, students are able to view multiple visual images of different fractions very quickly. They can see what each fraction looks like in both its symbolic and pictorial modes in the on-screen presentation. The connection of these visual and symbolic models through experimentation allowed students to rapidly view many different fractions from halves to 99ths. 2. Making conjectures: While using the Renaming Fraction applet, students were able to test what would happen to the visual images of the fraction pieces as they pressed the arrow keys up and down. This allowed them to test their hypotheses about fractions they thought might be equivalent to a given fraction. As they viewed numerous different visual images of the fractions, the applet may have facilitated their ability to

	look for and identify patterns in the fractions. This feature may have led them to a conjecture about a working rule for the patterns they were seeing. 3. Mathematical relationships. Students observed that the lines on the fraction applet that divided the whole region would not line up evenly when the pieces in the region were not divided by a common multiple. Each time students viewed a new fraction, the applet reinforced this mathematical principle. After working at their own pace with numerous fraction examples provided by the applet, students began to see mathematical relationships related to the factors and multiples of the numbers they were given. Task 2: Adding Fractions with Unlike Denominators 1. Linking symbolic and iconic modes: On this fraction applet, the symbolic and iconic manipulations are closely tied together during each step of the process. Students frequently have difficulty associating their manipulations with fraction pieces to the symbolic process of using algorithms. Although they may be successful manipulating physical fraction pieces, they may be unsuccessful at manipulating numeric representations because they see these as two separate processes. The addition of fractions using the virtual fraction manipulatives connected the processes students were using in finding common denominators and combining fraction pieces with the symbolic representation of these concepts. The first screen of the applet shows two fraction pieces with unlike denominators, which students rename using arrow keys. Students type in the numeric representation of the renamed fractions, and the screen changes to allow the student to perform the addition in both symbolic and iconic forms. After students type the numeric representation into the addition sentence, they receive feedback on the accuracy of their response 2. Preventing a common error pattern. One common problem in the addition of fractions with unlike denominators is known as the “add across” error where students add both the numerators and the denominators (Ashlock, 2002) (i.e., 1/3 +2/6= 3/9). Using this fraction applet, students are guided through the problem with the support of a visual model. In each problem, the concept tutorial does not allow students to add the numbers erroneously and waits until the two fractions have a common denominator. Only after students find common denominators are they permitted to begin the addition process. Within the addition mode, the ability to drag the shaded fraction pieces to the sum square/sum circle further reinforces the idea of combining like pieces to determine the numerator. Another feature is that the sum square/sum circle names the total divided parts of the denominator. Students using the concept tutorial to practice addition of fractions cannot make this common mistake because of the step-by-step process that includes both. Task 3: Fraction Track Game 1. Student-to-student communication.: The Fraction Tracks Game is designed for students to play the game in pairs. By allowing the students to work in pairs, students had the opportunity to talk about the mathematics involved in the game. The virtual environment served to facilitate students’ interactions with each other and with the computer. When one student made a move on the Fraction Tracks game board, the student’s partner occasionally questioned the student’s move. This led students to justify their choice of move and to explain why the move was mathematically accurate. Much of the mathematics talk during the class session focused on students’ agreement on whether or not a move on the Fraction Tracks board was legal mathematically. 2. Application of previously learned skills: Students used the skills of renaming fractions, finding common denominators, and fraction addition

	to play the Fraction Tracks Game. The students learned and reinforced these concepts by playing the game because it allowed them to rehearse and play several times to develop their strategies. During this rehearsal they began to recognize that they could use previously learned skills to improve their performance during the game and so they applied these skills. This enabled many of the students to attach meaning to equivalence and addition of fractions. However, although it was evident to the observers, it was not immediately obvious to students that they were applying previously learned skills to the new mathematical situation.
科技工具之特點	1. One characteristic afforded by the virtual manipulative concept tutorials used in this project was their design that combined both visual and symbolic images in a linked format. This may have encouraged students to make connections between these modes of representation and, thereby, developed students' representational fluency, particularly for visual learners 2. Another characteristic of these virtual fraction manipulatives was that the applets allowed students to experiment and test hypotheses in a safe environment. The guided format features of the applets allowed guessing and trial-and-error, and at the same time, would not allow students to submit an incorrect response. 3. Virtual manipulative technology is a promising tool for improving students' visual and conceptual abilities in mathematics. 4. The dynamic nature, along with color, graphics, and interactivity can capture and hold the attention of students so that they persist in mathematics tasks.

編號:3522

Data Extraction Form	
欄位名稱	內容
文獻來源	Wei, C. S., & Ismail, Z. (2010) Peer Interactions in Computer-Supported Collaborative Learning using Dynamic Mathematics Software. 8 (1), 600-608.
研究目的	We designed and implemented a systematic observation of students trying to cope with non-routine problems concerning the area of irregular plane figures either with or without the support of a computer with dynamic geometry software. The main idea was to pose non-standard problems in both environments, the paper-and-pencil and the computational ones, aiming to produce a feeling of need for verification in order to explore and compare the ways students respond.
研究問題	1. To what extent does the above-mentioned computational environment allows the development of verification processes in greater frequency and in a wider variety than in a typical paper-and-pencil situation? 2. Are these processes based completely on empiricism or not? 3. In case of processes that are not based on empiricism, could we order them according to their mathematical 'significance'?
研究方法	
教學單元	■數與運算(Number & Operations) □代數(Algebra) ■幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	The topic was the calculation and comparison of areas of irregular plane figures
教育階段	■國小□國中 □高中 52 students of the 5th grade and 46 students of the 6th grade of a primary school
融入教學之工具	The 5th grade used MSPaint (v.5.1) and GeoComputer (v1.0.); The 6th grade used Cabri Geometer (v.1.2.4.8.).
學習活動 (Learning activity)	教學策略: Two tasks for the 5th grade and two tasks for the 6^{th}. There were separate sessions for each group and the students had a session of 45 min per task. Each student worked individually on his/her own computer or his/her worksheet. In the case of the laboratory the students did not have the opportunity to choose the appropriate software.
所收集之研究資料	1. In the computer environment, aiming to record how the students used the technological tools for verification purposes, we used the Camtasia Studio, a software for screen capturing. 2. To follow the students' attempts to verify their solutions audio-taped interviews were used after the completion of each task so as to use more direct questioning concerning parts of their work that were less clear.
研究結果	Analysis resulted into three main categories into which the recorded verification strategies were classified. These categories were: 1. Empirical strategies (a) Visual verification: Students who employed this strategy accepted with no doubt the legitimacy of their results and this habit made them ignore results that would not stand logical analysis (b) Adaptation-based verification: In the laboratory students had the ability to make direct comparisons and to find relations between what they thought or what they expected as a result and what they saw on their computer screen. visualizing the results of their activities on the screen, they could immediately react to them so as to ultimately reach the correct result. In this process each step towards

	the solution of the problem is completely determined by what can be seen on the computer screen. This visual impression forces the students to react. 2. Numerical strategies (a) Formula-based verification: Using the tool "Calculate" of the software and applying the known formula. in the technological environment the formulas are written in a linear manner which demands more parentheses and makes the arithmetic operations which have to be done less obvious (b) Outline and auto-measure verification: This strategy emerged as an answer to the limitations posed by the software at a technical level. The "Area" tool of Cabri would give the students an answer concerning the area of the whole shape. They thought then to re-draw these sub-shapes by using certain tools.Working like that they made them recognizable to the program and now they were able to use the 'Area' tool to verify whether they correctly calculated the sub-areas. 3. Idiosyncratic strategies (a) "Copy–Paste" verification: This strategy was applied during the process of problem solving to verify intermediate results or statements. Students changed the orientation of these triangles so as to fit one to the other. Thus, they verified their initial thought which they had used for the calculation of the area of the initial shape, that the combination of these triangles would result in a whole square unit (b) Verification through erasing-and-redrawing: This technique could be regarded as an extension of the previous strategy of Copy–Paste. (c) Transformation-based verification: In this strategy the students tried to transform an unfamiliar shape to a familiar one: a triangle, square, or rectangle. The strategy of transformation is conducted through successive cut and paste actions which implies that one is familiar with the idea of the preservation of area. (d) Properties-based verification: It would be considered as an intermediate verification that facilitated students in deciding how to proceed in order to achieve sub-goals.
科技工具之特點	1. What they 'see'. The image itself can justify the students' choices. This becomes more powerful in the computer environment since the students can manipulate the image in various ways 2. Visualizing the results of their activities on the screen, they could immediately react to them so as to ultimately reach the correct result. In this process each step towards the solution of the problem is completely determined by what can be seen on the computer screen. This visual impression forces the students to react.

編號:3902

Data Extraction Form	
欄位名稱	內容
文獻來源	Ozgun-Koca, S.A. (2008). Ninth Grade Students Studying the Movement of Fish to Learn about Linear Relationships: The Use of Video-Based Analysis Software in Mathematics Classrooms. Mathematics Educator, 18(1), 15-25.
研究目的	The present study focused directly on the effects of the linking property of the software on students' learning. The goal was to see how this feature of the software affected their learning and understanding of the relationships between the representations and the mathematics content itself. The major aim of this paper, however, is to present an activity for both linked and semi-linked versions of the software in order to demonstrate the use of the software with the aim of connecting practice with research.
研究問題	
研究方法	This study used a mixed method design. In an eight-week period, 20 Algebra I students, separated into two groups, used VideoPoint: one group used linked representation software and the second group used semi-linked representation software. Four computer lab sessions were spaced out during the data collection period. Because this particular school schedules its classes for 78 minutes, one group was taken out of the classroom for a 35-minute computer lab during the first part of the class; then during the second part, the other group went to the computer lab.
教學單元	□數與運算(Number & Operations) ■代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	Linear Relationships
教育階段	□國小 ■國中 □高中 Ninth Grade Students
融入教學之工具	Multi-representational software
學習活動 (Learning activity)	教學策略:
	＊An activity using multiple representational software. The parallel tasks for the linked and semi-linked versions are displayed in two columns. The activity included five main sections: namely an introduction section; three sections that focus on the graphical, tabular, algebraic representations separately; and a general questions section at the end. Two students' responses are provided, one using the linked version, the other student using the semi-linked version of the software. Even though just two students' responses are displayed below in the tables, general conclusions from the larger study and general comments about the use of different versions are also included in the narrative. The lab activity started by watching a movie: two fish swimming at a constant rate across the screen towards each other. The fish movie was obtained from Graph Action Plus. A grey fish (the fish at the bottom of the screen) swims from right to left and a striped fish (the fish at the top of the screen) swims from left to right. Students were asked general questions about the movie, such as, "How does the distance between the two fish change as they swim?" At this point, only the movie window was open on the screen. Typical responses included, "At first they got closer and closer together and then they got farther and farther away." The second part of the activity focused on the graphcal representation (see Table 1). First students were asked to create the graph of the phenomenon by paper and pencil after watching the movie. Before seeing

	the computer-produced result could be very effective in creating environments for students to construct linkages among representations (i.e., between the movie and the graph in this case). This approach was used throughout the activity with all representations. After making their predictions, students opened and observed the computer-produced graph. This gave them a chance to check their work; differences existed between both students' hand-produced graphs and the computer-generated graphs. The linked group student's graphs were switched. The grey fish was the one whose distance was decreasing whereas the striped fish was the one with increasing distance. The semi-linked group student, on the other hand, provided increasing graphs for both fish. Because of these discrepancies, the students may have experienced disequilibrium and needed to accommodate this new information. With the help of the software, the linked group student used the linkage and accommodated the new information. Even if the version of the software did not provide linkages among representations for the semi-linked group student, the information provided by the representations helped him to re-think his prediction and compare them with the computer-produced representation. In the next task, students were asked to identify and describe the point on the graph that represents where the two fish meet. The linked group students could use the linkage and identify the point on the graph without needing more explanation. They sometimes only referred to the movie, saying something like, "Just look at the movie. This is the point where the two fish meet," after double clicking on the graph. The semi-linked group students, on the other hand, did not have this kind of opportunity. This lack of linkage between the movie and the graphical representation seemed to force some of the semi-linked group students to provide richer explanations such as, "They are at the same place at the same time." A similar approach was followed for the tabular representation. First students were asked their predictions about the table of values. Then they were asked to complete a table by reading values for the graph. Both students in Table 2 had the same trouble—reading values from the graph. For instance, after the linked group student located the time that the striped fish was 50 pixels away on the graph successfully she was asked to locate the distance of the grey fish at that time (approx. 0.42 seconds). Instead of moving vertically to the point labeled # 2, she moved her cursor horizontally to the point labeled as #3 to read the distance of the grey fish at 1 second. The linkage could be helpful to both students. If the linked group student used the linkage and clicked on the point # 1, point #2 would be circled. However, the linked group student did not think of using the linkage at this point, and the semi-linked group student did not have this option. When students were asked to identify and discuss the point in the table that represents where the two fish meet, the semi-linked group student was able to construct a linkage by using the information provided by the multiple representations. He used the graphical representation (that he used previously to answer a similar question) in order to interpret the tabular representation more effectively. The linked group student, on the other hand, attended to the distances of both fish from the left-hand side of the movie screen. At one data point, one fish was closer to the left-hand side of the screen and then at the next data point the other fish was closer to the left-hand side of the screen. So she concluded that the fish should meet between those data points. The third section of the activity focused on the algebraic representation. Students were asked to make predictions about the symbolic representation of this phenomenon. This part was the most difficult section for the students. The two students in Table 3 were representative of many students who could not predict or even start to think about the symbolic form. Whereas linked group students had easy access to the

	algebraic form, the semi-linked group students needed to predict the coefficients of the equation. When the semi-linked group students entered their predictions, the line for their last two predictions appeared on the graph window. This feature of VideoPoint showed students how well their predictions fit the data points and how the changes in the algebraic form affected the graph. Because the computer software creates linkages between the symbolic and graphical representations, students can focus on how manipulating the algebraic form in a specific way causes changes in the graph. Many students had difficulties interpreting the algebraic form and using the equations to predict the time where the two fish meet. When finding the time that the two fish meet by using the graph or the table, students were able to make connections to the context (movie) more easily than when asked to use the algebraic form. The interpretation of the algebraic model and the symbolic manipulation required are possible reasons that students struggled more in this part of the activity. The final section included a general question, such as identifying the distance between the two fish at the beginning of the movie. The students were allowed to use any representation they wished to answer this question. Students reported the representation they used and were encouraged to use other representations to answer the same question. The linked-group student used a table effectively to answer this question. When asked to use the graph, she used the linkage, clicked on the data point on the graph and saw both points circled at the same time. The semi-linked group student also approached the question using a tabular representation: "You could subtract these two distances [pointing to the first distances at the table]." When he was asked to use the graph, he said, "You would take the beginning from right here [pointing to the first data point of the striped fish on the graph] and that beginning right up there [pointing to the first data point of the gray fish on the graph] and subtract them."
所收集之 研究資料	Data collection methods included mathematics pre-and post-tests, follow-up interviews after the mathematics post-test, clinical interviews in the computer lab at the end of the treatment, classroom and lab observations and document analysis (classroom materials, computer dribble files, exams, and assignments). A grounded survey was conducted at the end of the study in order to see students' opinions about mathematics, representations in general, and the computer environment.
研究結果	＊This study focused on the effects of the use of a multiple representational computer environment on students' learning. Results suggested that in a semi-linked environment, students seemed to rely mainly on their own existing knowledge with the help of the software to respond to a question. Although this environment did not provide such rich feedback as in the linked environment, ready-made graphs or tables presented powerful visual information/feedback for students to use while answering the questions. The software could have served as helper, record keeper, or representation provider for the students. Without the linkage, students seemed to provide more mathematically based explanations rather than movie-based explanations and constructed the linkages between representations for themselves. They were seen to be in a more active role mentally as learners.
科技工具之特點	Semi-linked representations can be as effective as linked representations for mathematical concept development. The most beneficial usage could come from using a linked version to introduce a mathematical idea and help students construct their schema. Once accomplished, the linkage could be removed and the semi-linked version could be turned on in order to make students use their newly constructed schema.

編號:4140

Data Extraction Form	
欄位名稱	內容
文獻來源	Lan, Y.-J., Sung, Y.-T., Tan, N.c., Lin, C.-P., & Chang, K.-E. (2010). Mobile-Device-Supported Problem-Based Computational Estimation Instruction for Elementary School Students. Educational Technology & Society, 13 (3), 55–69
研究目的	This study implemented a three-stage problem-based estimation instruction scenario and combined it with mobile technology to provide elementary teachers with an effective e-tool for observing student estimation and leading effective class or group discussions on the selection and assessment of appropriate strategies for solving daily estimation problems
研究問題	
研究方法	This study adopted a mixed research approach, simultaneously gathering both qualitative and quantitative data. Randomly sampled and assigned to two groups: the experimental group (problem-based estimation instruction using mobile devices) and the control group (problem-based estimation instruction without mobile devices).
教學單元	■數與運算(Number & Operations) □代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	Four units teaching the following estimation strategies: front-end, clustering, rounding, compatible numbers, special numbers, and initial estimate adjustment and refinement.
教育階段	■國小□國中 □高中 Twenty-eight fourth graders
融入教學之工具	Mobile-Device：The Group Scribbles platform. Group Scribbles (GS)
學習活動 (Learning activity)	教學策略: problem-based instruction
	＊The experimental group (problem-based estimation instruction with mobile devices)；the control group (problem-based estimation instruction without mobile devices), each of which thus contained 14 students. The experimental group： Received 30-minutes of training on using the Tablet PC and GS system, after which all students were administered a pre-test involving CEA assessment. Then four units, each lasting 80 minutes, were taught during the 4-week experiment. Each unit comprised three instruction stages: strategy introduction, individual practice, and group cooperation. Each student in the experimental group was equipped with a Tablet PC. The students logged into GS, and the teacher then grouped them into small estimation groups of three or four members. During the strategy introduction stage, were embedded in various learning activities following a “personal estimation – whole class judgment” cycle. The teacher first presented a problem-based story to the class and led them in helping the main character in the story to solve problems. After the character encountered a computational estimation problem, the teacher asked each student to estimate the solution. Students wrote or typed their ideas or estimates on the e-sticky notes and dragged them to the public area for sharing with the whole class. Subsequently, the class discussed various estimation strategies and selected the best. Once the class reached agreement, the teacher continued the story and led the class to solve another problem to help the students practice estimation and learn the target estimation skills. The story was followed by a series of practice

	problems, comprising the individual practice stage. All students were asked to solve the estimation problems and shared and discussed their solutions with the class. The group cooperation stage followed soon after the individual practice stage, during which students learned the target skills contained in a single unit. During this stage, the teacher presented a real world problem and asked students to cooperate to develop a suitable solution. Each member of each small estimation group wrote down their estimate on an e-sticky note and then dragged it to the group area to show their groupmates . The group members then discussed and tried to reach agreement on a strategy to be shown in the public area. The teacher then led the class in assessing the estimates of the various groups. ＊The control group Received estimation instruction materials and instruction flow identical to those described above, but simply wrote down their estimates on the sticky notes.
所收集之 研究資料	1.The qualitative data: Two observers recorded the treatment activities using two digital video cameras (each camera focused on one of the small estimating groups). After completing each unit, the two observers compared their observation results. Furthermore, following treatment the observers reviewed the videotapes of the group estimating process, focusing their observations on the following: (a) individual estimation, (b) self-reflection regarding their estimations, and (c) group cooperation to solve real world estimation problems. 2. The quantitative data: This study adopted an experimental design. All participants were administered a computational estimation test before and soon after treatment. Student test scores were gathered and analyzed to check whether the two groups performed or progressed differently in terms of computational estimation skills. Furthermore, to understand whether students selected appropriate estimation strategies or problem solving; following the post-test all the students were asked to write down the strategies they used to solve a real world problem which is described in the section on the assessment instruments.
研究結果	The analytical results demonstrated that problem-based estimation instruction could effectively help students learn computational estimation skills. Moreover, using mobile devices for problem-based computational estimation instruction appeared to help students discuss and cooperate with others, and moreover the mobile-device-supported problem-based estimation scenario helped students develop metacognition knowledge of estimation strategies.
科技工具之特點	The blending this scenario in a mobile-device-supported cooperative learning environment helped students cooperate and thus appears to benefit not only the development of estimation skills in elementary students, but also that of metacognition knowledge of estimation strategies.

編號:4148

Data Extraction Form	
欄位名稱	內容
文獻來源	Hwang, W.-Y., Su, J.-H., Huang, Y.-M., & Dong, J.-J. (2009). A Study of Multi-Representation of Geometry Problem Solving with Virtual Manipulatives and Whiteboard System. Educational Technology & Society, 12 (3), 229–247.
研究目的	The proposed system was evaluated with one pilot study to investigate its perceived ease of use and usefulness. Furthermore, students' solving strategies were analyzed using their manipulations in the 3D space and solutions recorded in the whiteboards.
研究問題	How the VMW system supports multi-representation transformation?
研究方法	Twenty three 6th grade elementary students participated in this research. The students followed their Math teacher's instruction to solve eight geometry problems. The perceived acceptance of the proposed VMW system and its influences on geometry concept learning were investigated.
教學單元	□數與運算(Number & Operations) □代數(Algebra) ■幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	Geometry problem posing and solving (area and volume reasoning problems)
教育階段	■國小□國中 □高中 Twenty three 6th grade elementary students
融入教學之工具	Virtual Manipulatives and Whiteboard, or VMW. In the VMW system
學習活動 (Learning activity)	教學策略: Two pedagogical concepts, constructivism and multiple representation transformation,
	＊Since the proposed VMW system can be accessed from a website, teachers and students can easily engage themselves in problem solving anywhere and anytime if Internet access is available. In the beginning, teachers organized and stacked geometric objects to build geometry problems in the 3D space and gave problem descriptions on a virtual whiteboard. Students then started to solve problem and to express their solutions on their own virtual whiteboards. When students completed their answers, a peer review session was started. In this session, students were asked to review the answers of others and to critique their work using the virtual whiteboard. Students could therefore continually revise their answers, affirm or refute the work of others and engage in discussions of the work until the next problem was posed. 1. In the beginning, teachers first posed a new geometry problem with the VWM system, in which a 3D theme was built, with a problem description given in the whiteboard. All students studied the new geometry problem given by teachers and gave their answers by clicking a circular icon Students could also revise their solutions many times by replying their previous answers or by giving comments to others solution via others' discussion thread. The VMW system, combined with discussion thread, provides an asynchronous collaboration model. Its implementation is easier than a synchronous model. 2. Students can study the problem by manipulating 3D objects, and then choose appropriate viewpoints to create their own translucent whiteboards. The whiteboards can help them to find out the solutions via observation of the manipulated 3D theme behind of the whiteboards. 3. After the teacher initiates a new question, students can collaboratively discuss the question by generating their own translucent whiteboards combined with 3D scene behind. One was created by the teacher and two

	were created by students. Teacher used one whiteboard to describe geometry problems, while on the students' whiteboards they discussed how to solve the problem together.
所收集之 研究資料	perceived acceptance questionnaire、interviews
研究結果	一、量化 1. It was found that most subjects agreed that the VMW can help them to use different representations for solving geometry problems as well as facilitating and broadening their thinking from different viewpoints in the 3D theme. Meanwhile, they think the VMW can help them to show their solutions more completely. 2. The high scores on the perceived usefulness questionnaire showed the proposed system and the multi representation transformation mechanism were considered to provide some help in geometry problem solving by students. Most questions for assessing usefulness of the system were related to multi-representation, such as using 3D block as the concrete representation and using the multimedia whiteboard for expressing ideas with abstract symbols. 二、質性 1. Students felt more comfortable when they used pen and paper for Math reasoning work. To promote students' use of the whiteboard tool in addition to pen and paper, researchers have decided to implement some calculating widgets to help with Math reasoning in a future release of the VMW system. 2. The students were highly motivated by the interesting, fresh, new 3D manipulative software. Such an effect may have caused students to put more effort than usual into using the tools to explore geometry problems. Therefore a longer study is needed to determine if student enthusiasm and interest stemming from the novelty of the new tool was more responsible for improved performance than the tool itself.
科技工具之特點	1. The ability to share their ideas, and to affirm, refute and respond to the work of their peers, as facilitated by the VMW system, helped the students to clarify their thinking about mathematical problem solving. 2. With the asynchronous discussion board and teacher's encouragement, most students were willing to use the system to describe their ideas and solutions clearly and thoroughly. Through this kind of interactive communication, more correct answers and meaningful responses to others' comments or queries were derived.

編號:4151

Data Extraction Form	
欄位名稱	內容
文獻來源	Scheiter, K., Gerjets, P., & Schuh, J. (2010), The acquisition of problem-solving skills in mathematics: How animations can aid understanding of structural problem features and solution procedures, Instructional Science, 38(5), 487-502.
研究目的	For the purpose of exploring the potential of animations to counteract these problems associated with learning from worked examples, hybrid animations were developed.
研究問題	we tested the assumption that hybrid animations, where a realistic animation of the problem statement is morphed into a more abstract representation of the problem statement and of subsequently carried-out solution steps, can improve problem-solving performance compared to a text only version of the instructional materials.
研究方法	The experiment was divided into two phases, a learning and a test phase.
教學單元	□數與運算(Number & Operations) ■代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	solve algebra word problems
教育階段	□國小 ■國中 □高中 32 pupils (9th grade) from a German high school
融入教學之工具	Hybrid animations
學習活動 (Learning activity)	教學策略: Worked examples combined with hybrid animations、problem-solving skills.
	During the learning phase pupils were asked to read three textbook chapters on different school subjects, namely biology, chemistry, and politics, which were presented on the computer screen. Embedded in each of the three chapters were three algebraic worked-out examples that illustrated how to solve specific problems in these domains. For each of the nine worked-out examples the solution formula as well as each step of the solution procedure were presented. Within each chapter, the three worked-out examples differed with regard to the complexity of their underlying solution procedure and required a different algebraic formula. These three formulas were identical across the three school subjects. Thus, participants read nine worked-out examples embedded into three different domain contexts (variation of superficial example features) and they were confronted with three different algebraic formulas (variation of structural example features). Depending on the experimental condition the worked-out examples were either presented as text-only or they were accompanied by a dynamic visualization of the problem statement and the respective solution procedure.
所收集之研究資料	An analysis of the frequency of retrieving animations for the nine examples
研究結果	Learners with hybrid animations showed superior problem-solving performance for problems of different transfer distance relative to those in the text-only condition. (There was a significant overall difference between the two instructional conditions, revealed that the effects in favor of hybrid animations became stronger with increasing transfer distance.)
科技工具之特點	Effectiveness of hybrid animations was explored, which explicitly show the transition from a concrete representation of the problem statement to the abstract representation necessary to construct a problem model.

編號:4636

Data Extraction Form	
欄位名稱	內容
文獻來源	Wong, W.-K., Yin, S.-K., Yang, H.-H., & Cheng, Y.-H. (2011). Using Computer-Assisted Multiple Representations in Learning Geometry Proofs. Educational Technology & Society, 14 (3), 43–54.
研究目的	This study investigates how students would react to the use of multiple representations such as proof tree, formal proof and dynamic geometry figure when they read a proof and construct a proof in the system.
研究問題	1. Which representations students prefer when they perform tasks related to theorem proving in MR Geo? 2. After using MR Geo, will students' attitudes towards learning geometry undergo any change? Which types of students benefit more from multiple representations in MR Geo?
研究方法	In order to understand the effect of MR Geo on junior high school students' learning of geometry proofs, we conducted an experiment that spanned six weeks. This experiment used materials on parallelograms and triangles from textbooks and reference books for grade nine mathematics that covered basic algebraic concepts (such as equality axiom), properties and elements of geometry (such as perpendicular bisectors, angle bisectors), and similarity and congruence of triangles.
教學單元	□數與運算(Number & Operations) □代數(Algebra) ■幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	Geometry proofs
教育階段	□國小 ■國中 □高中 96 ninth grade students selected from three classes in two public junior high schools in southern Taiwan.
融入教學之工具	A computer-assisted learning environment called MR Geo is proposed to help students in learning to do theorem proving, with the help of multiple representations including problem description, static figure, dynamic geometry figure, formal proof and proof tree.
學習活動 (Learning activity)	教學策略:
	Task 1 Finding missing inference steps: To recover the missing nodes of a proof tree, the students can interact with the problem, the formal proof, the static figure, or the dynamic geometry figure. By observing the mutual correspondence among these representations, the students might improve their comprehension of the formal proof. In particular, if a student can translate the formal proof into a proof tree, she should be able to recover the missing nodes. Task 2 Local theorem proving: Some steps in the formal proof are missing. In the form of multiple-choice questions (select one of 4 choices), the system asks students to fill in the missing deductive steps. students can obtain relevant information by reading the proof tree and dragging the dynamic figure to check candidate propositions. The main purpose of this task is to help students complete a formal proof after they have read and understood the proof tree. Task 3 Translation of a proof tree into a formal proof: Students are asked to construct a formal proof by dragging nodes of the proof tree and drop into rows of the formal proof frame. Moreover, they can reorder the rows by dragging them around. In this way, they can explore different orderings of the steps. They can interact with the problem representation

	or the visual representations whenever they want to check any geometric features or propositions. The major purpose of this task is to improve students' understanding of how to write a complete formal proof. Task 4 Concept testing: The main purpose of this task is to test students' basic geometric concepts. Students are asked to pick geometric objects from a figure or answer multiple-choice questions. Consider the question in as an example: "Please indicate on the figure a pair of alternate interior angles in the top right frame of the screen." Students can use the mouse to select a geometric object such as "line", "angle" by clicking at the object on the static figure.
所收集之 研究資料	Questionnaire survey
研究結果	Empirical results indicated that medium-achievement students enjoyed most in interacting with these representations and found them most helpful in learning geometry proofs while low-achievement students changed their attitudes of hating geometry theorem proving. 有五種表徵(Representation)形式： Problem、Static figure、Dynamic geometry figure、Formal proof、Proof tree、 1. Students' Interactions with Representations in MR Geo： In problem representation, students usually spent little time to review the question after them have read and understood the given conditions and goal condition. Although students could consult the static figure to check given conditions, they were unable to manipulate the static figure freely like dynamic geometry figure. The interaction frequency of dynamic geometry figure was significantly lower than the other three representations. These numbers showed that MG students interacted with representations most frequently, followed by LG students and HG students. MG students interacted more with multiple representations, they had more chances to build up the connections between these representations. Their learning may benefit most from these interactions. This is an interesting problem worthy of further study. 2. Students' Preferences of Representations： HG and MG students liked the formal proof and proof tree more or less the same. This indicates that HG and MG students might know that these two representations express similar information and they can be translated into one another. However, for LG students, a graphical proof tree seems to be more revealing and a better alternative to a formal proof. Students' relative preferences in dynamic geometry figure are quite interesting. For both HG and MG students, dynamic geometry figure is much less attractive than formal proof and proof tree. In contrast, LG students preferred dynamic geometry figure, formal proof and proof tree in this order. HG students could understand formal proof and proof tree well enough that they did not need to consult the dynamic figure. MG and LG students did not know how to check the validity of geometric conditions with a dynamic figure. LG students liked to play with dynamic figure because they were attracted by the intriguing dynamics. Although playing with a dynamic figure did not help their understanding of a proof in general, a DGE could make geometry more interesting and attractive to them. 3. Students' Reactions to MR Geo The results also indicated that over 85% of the 96 ninth grade students agreed that proof tree can help them better comprehend a geometry proof.
科技工具之特點	1. MG students interacted more frequently with representations than HG and LG students: HG students were more comfortable in using a forma proof so their interactions with other representations were not as frequent

	as MG students. LG students, with a weaker background in math, might not improve their performance by much even with more interactions with the representations. In this way, MG students might benefit most from their interactions with the representations in MR Geo. 2. Multiple representations improved students' perspective of geometry proof: Problem description, static figure, dynamic geometry figure, formal proof and proof tree had different effects on students. In particular, problem description and static figure could assist students' understanding of the problem context and only a few HG students said that dynamic geometry could help them confirm or reject a proposition. The connection between formal proof and proof tree raised students' comprehension of geometry proof. Some LG students indicated that after understanding the geometry proving process, they no longer hated geometry classes. The above results indicated that MR Geo might offer an attractive, alternative approach to geometry education with multiple representations in a computer-assisted learning environment, comparing to traditional classroom teaching.

編號:4662

Data Extraction Form	
欄位名稱	內容
文獻來源	Burns, B.A., Hamm, E.M. (2011). A comparison of concrete and virtual manipulative use in third and fourth grade mathematics. School Science and Mathematics Journal (111)6, 256-261.
研究目的	The primary purpose of this classroom experiment was to examine the effectiveness of concrete (hands-on) manipulatives as compared with virtual (computer-based) manipulatives on student review of fraction concepts in third grade and introduction of symmetry concepts in fourth grade.
研究問題	
研究方法	A pretest–posttest design was employed with a sample of 91 third-grade students and 54 fourth-grade students who were randomly assigned to complete a lesson using either concrete or virtual manipulatives.
教學單元	■數與運算(Number & Operations) □代數(Algebra) ■幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	三年級: the fraction unit (primarily equivalent fractions, ordering fractions, and mixed numbers) 四年級:幾何對稱(symmetry)
教育階段	■國小 □國中 □高中 Third- and fourth grade students , elementary school
融入教學之工具	virtual manipulative(from Web sites)
學習活動 (Learning activity)	教學策略:探索式學習
	三年級 Pairs of students .The virtual manipulative group was directed to two different Web sites: www.visualfractions.com, a tutorial that models fractions with number lines or fraction circles; and nlvm.usu.edu, a site linked to NCTM standards from which students explored renaming fractions using fraction squares or fraction circles. Both sites provided immediate feedback as students worked through problems. Although not utilized by the students for this class lesson, both sites contained tutorials, games, and links to additional math resources, which could be used to reinforce skills. In addition to the Web sites, the fraction bars activity from the software program Hands-on Math (Ventura, 2001) was also used. All students were responsible for completing the same worksheet based on their work with manipulatives; however, the worksheets were not graded and the students were aware that the worksheets were for the in-class activity only. Each group had approximately 20 minutes per activity for a total class time of one hour. 四年級 Students work in pairs. The virtual manipulative group was directed to two different Web sites to complete activities, whereas the concrete manipulative group worked on activities with the manipulative Mira. Web sites used were nlvm.usu.edu, where students explored the sketch pad to learn about reflection symmetry, and www.mathsnet.net, in which students explored transformations-reflections through a hit the target activity and a playing-with-reflections activity. groups worked on their respective activities for 60 minutes while completing a nongraded worksheet.
所收集之研究資料	pretest to posttest
研究結果	Results of the posttest suggest that student learning was unchanged by lesson condition.

	三年級 Virtual third-grade manipulative groups showed improvement from pretest to posttest, there was no statistically significant difference in the pretest and posttest scores of third graders' fraction knowledge. 四年級 Fourth-grade students also demonstrated posttest gains for both manipulative groups with the concrete group outperforming the virtual manipulative group in mean test scores; however, this difference was also not statistically significant.
科技工具之特點	Virtual manipulatives is the immediate feedback available to the student. This may be especially important for independent class work or homework. The feedback can potentially allow the student to self-correct in a nonthreatening environment.

編號:5783

Data Extraction Form	
欄位名稱	內容
文獻來源	Biza, I (2011). Students' Evolving Meaning About Tangent Line with the Mediation of a Dynamic Geometry Environment and an Instructional Example Space, Technology, Knowledge and Learning, 16(2), 125-151.
研究目的	The study presented in this paper focuses on the evolution of students' personal meaning of tangents in a classroom discussion through the mediation of the inscription of local straightness in the DG environment and the instructional example space prepared especially for the needs of the teaching experiment.
研究問題	
研究方法	In this paper I report a lengthy episode from a teaching experiment in which 15 Year 12 Greek students negotiated their definitions of tangent line to a function graph. In this paper I presented an episode from a Year 12 teaching experiment that focused on the introduction to the tangent line of a function graph, and its relationship to the derivative. The teaching experiment had the characteristics of the diagnostic teaching methodology proposed by Bell (1993). According to this approach, firstly, key conceptual points and misconceptions regarding tangent line of function graph should be regarded through reference to existing research and by testing directly the students to be taught. Then the teaching is designed to focus on the above points, giving the students challenges, provoking cognitive conflict by exposing potential misconceptions, and resolving them through discussion.
教學單元	□數與運算(Number & Operations) ■代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	1. Examination of generalisable properties of tangency (e.g. the tangent ine as the limiting position of secant lines and the linear approximation of the curve) in the case of circle. 2. Examination of the above properties in the case of semicircle. 3. Introduction to the definition of the derivative and the tangent to a function graph. 4. Establishment of these definitions in classroom discussion through critical examples of function.
教育階段	□國小 □國中 ■高中 15 Year 12 students (aged 17–18 years) of a Greek secondary school
融入教學之工具	EucliDraw(Dynamic Geometry software with Function Grapher tools) ：Dynamic Geometry software(that combines Dynamic Geometry (DG) and Function Grapher (FG) facilities, was employed)
學習活動 (Learning activity)	教學策略: The students worked in groups of three in each of the five computers and they kept notes on worksheets prepared for the needs of the experiment. During the experiment I was operating the sixth computer connected with the projector, keeping notes on the blackboard and wandering around the class in order to monitor the progress of group work and orchestrate the classroom discussion.
所收集之研究資料	Data was collected through pre- and post- teaching experiment questionnaires, audio recording of the whole-class discussion during the experiment, students' responses on the worksheets and my notes.
研究結果	The analysis indicated that the evolution of students' meanings towards a more sophisticated understanding of tangency was not linear. Also it was interrelated with the evolution of the meaning they had about the inscriptions in the electronic environment; the instructional example

	space; the classroom discussion; and, the role of the teacher. According to these results, students' perspectives about tangents were expected to be strongly influenced by the mathematical contexts and the representational systems in which they had met the notion before.
科技工具之特點	The electronic environment should facilitate students in: 1.Their transition from the geometrical context to the analytical context and the connection between these contexts. 2. Their exploration of mathematical properties across different but connected representations (e.g. graphical and symbolic). 3. Their access to different mathematical aspects of the same concept, in this case the tangent line. To meet the above aims we needed an electronic environment that: 1. Offers a friendly interface that integrates geometrical (DG) and analytical (FG) properties. 2. Offers different and connected representations 3.Facilitates the easy access to accurate, or as accurate as possible in an electronic environment, inscriptions of different aspect of the same notion and in different example. ＊The dynamic aspect of the instructional example space implies that the set of example needs not only to be well prepared and rich but also to be flexible enough to adjust to unpredictable students' responses.

編號:6057

Data Extraction Form	
欄位名稱	內容
文獻來源	Kong S. C. (2008) .The development of a cognitive tool for teaching and learning fractions in the mathematics classroom: A design-based study. Computers & Education, 51(2),886-899.
研究目的	An evaluation in the form of pre-test–post-test control group, quasi-experimental study was conducted afterwards to investigate the effectiveness of the enhanced GPM.
研究問題	Three research questions were posed in this empirical study: 1. What are the learning achievements of students of varying mathematical abilities after using the GPM for learning? 2. What are the justifications of teachers for the use of the GPM in teaching? 3. What is the preference of students for the use of the GPM for learning?
研究方法	A quasi-experimental study of the enhanced CT derived from the second cycle of design-based research, this article reports the findings of a pre-test–post-test control group empirical study using the enhanced CT in the classroom.
教學單元	■數與運算(Number & Operations) □代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	Fraction equivalence and addition and subtraction of fractions with like and unlike denominators.
教育階段	■國小□國中 □高中 Senior primary mathematics
融入教學之工具	A web-based CT called the "Graphical Partitioning Model (GPM)"： The GPM is a graphical model, a rectangular bar that represents both the part-whole perspective and the measure perspective of fractions.
學習活動 (Learning activity)	教學策略:
	＊The experimental group: Which was called the GPMGp group；the control group which was called the TradGp group. ＊The major learning and teaching activities for students in the experimental group: The major teaching materials for the experimental group of students included the GPM and a set of activity worksheets that guided students to explore the subject with the GPM. Each student was assigned a desktop computer to access the GPM which was located in a web server. The majority of class time was spent on the use of the GPM for the completion of the activity worksheets. Initially, the use of the GPM was introduced to students by teachers. Students were subsequently asked to explore the concepts of the target topic and complete the questions on the activity worksheets with the use of the GPM. Guidance and probing questions were given by teachers. Reciprocal tutoring among students was encouraged before checking the answers. In the answer-checking sessions, teachers asked some students to explain their answers. Class discussions and small group tutorials were occasionally conducted for students to consolidate their knowledge. The major learning and teaching activities for students in the experimental group in this study： 1. Brief of the functions of the GPM: The teachers introduced the use of the GPM. 2. Exploration of the target subject and completion of activity worksheets: Students were asked to use the GPM to explore the subject of common fractions and fraction operations by completing activity worksheets in each lesson. Relevant guidance and probing questions were

	offered occasionally by the teacher during these sessions. 3. Reciprocal tutoring: Students who completed the activity worksheets were asked by teachers to help their less capable classmates to finish the learning activities. 4. Answer check: Students were requested by the teachers to give answers and corresponding explanations for the tasks on the activity worksheets. Class discussions and small group tutorials were occasionally conducted for students to consolidate their knowledge. ＊The major learning and teaching activities for students in the control group: The major teaching material was the school textbook. The learning and teaching activities for the students in the control group focused on traditional, teacher-centred instruction of fractions. The majority of class time was spent on the completion of class work consisting of questions from the textbook. Initially, teachers either used diagrams or paper folding to explain the concept of fractions, or wrote examples on the blackboard to illustrate steps in fraction operations. Students were then asked to complete questions in the textbook. Guidance and probing questions were occasionally given by teachers. In the answer-checking sessions, students were selected by teachers to explain their answers. The major learning and teaching activities for students in the control group: 1. Instruction in the target subject: The teachers either used diagrams or paper folding to explain the concept of fractions, or wrote examples on the blackboard to illustrate steps in fraction operations. 2. Completion of class work: Students were asked to complete questions in the textbook. Relevant guidance and probing questions were offered occasionally by the teachers. 3. Answer check: Students were selected by the teachers to share their answers and provide corresponding explanations. The selected students were normally asked to write their work on the blackboard for class discussions.
所收集之 研究資料	Pre-test and post-test、teachers for the use of the GPM in teaching, semi-structured, individual interviews with the teachers、students for the use of the GPM in learning, a questionnaire.
研究結果	The results indicate that there were no statistically significant differences in learning outcomes between the exploratory learning approach, using the CT, and the traditional direct teaching approach. The CT enabled students to generate a procedural knowledge of adding and subtracting fractions with like and unlike denominators through an exploratory learning process. Teachers asserted that the CT was effective for stimulating reciprocal tutoring among students, and students were enthusiastic about using the CT as an educational tool. Hence, the CT has potential for further development as a tool for promoting collaborative learning in the classroom.
科技工具之特點	The GPM is a graphical model, this graphical representation aims to facilitate the students' initial understanding of the part-whole view of fractions since the parts in the rectangular bar are evident. The graphical model also allows students to associate fractions as parts of an extended set of whole number because the linear-shaped rectangular bar links the fraction representations with a linear measure of rational numbers. Consequently, the graphical model serves well to provide meaningful referents for the comprehension of the abstract meaning of rational numbers, and for the reflection of the structure of mathematical operations of rational numbers. The GPM has three key features for learning fraction equivalence. The three elements aim to facilitate students' understanding of adding and subtracting fractions with like and unlike denominators.

	1. The first feature demonstrates the comparison of the equivalence of fractions. This feature is developed in response to the difficulties encountered by students who do not think to represent fractions with the same unit to compare their value. An animation that shows the direct comparison of the equivalence of two fraction bars is triggered by dragging a fraction bar and dropping it onto another bar. The animation is designed to allow an extra comparison of fraction value, in addition to the visual inspection of the two separate fraction bars. This feature affords students multiple opportunities for comparing fraction equivalence in an interactive way. 2. The second feature is a graphic that illustrates the partitioning of a number into parts, or fractions. The graphic allows students to choose between an intentional slow-motion animation showing the partitioning or regrouping process, and an instantaneous change that shows the results of the partitioning or regrouping process. The graphical simulation of the partitioning process addresses the inabilities of those students who have difficulty representing fractions in a form conducive to comparing their value. It also addresses their failure to recognise the inverse relationship between the number of parts and the size of a part of a unit. This feature allows students to partition fractions by clicking the graphical representations of those fractions according to their abilities. Students who are more adept are able to generalise their understanding by viewing the instant partitioning model. Less capable students are able to comprehend the concept by activating the slow-motion animation of the partitioning process. 3. The third feature involves hypothesis-testing, with the interface , and addresses the problems of students who lack the ability to find equivalent fractions systematically. The hypothesis-testing interface asks students to test possible fraction equivalent states by adjusting parameters c and d, and allows them to compare fraction equivalence using the aforementioned comparative animation by dragging the fraction bar of the hypothesised fraction and dropping it onto the fraction bar of the original fraction.

編號:6059

Data Extraction Form	
欄位名稱	內容
文獻來源	Ivy Kidron, and Nurit Zehavi.(2002). The role of animation in teaching the limit concept. International Journal of Computer Algebra in Mathematics Education. 9(3), 205-27.
研究目的	The study examined the effect of using animation generated by a Computer Algebra System in understanding the limit concept in an experimental course given to eleventh grade high school students. Investigation into how animation was used to improve student's comprehension of the limit concept in an experimental course in which main topic were Approximations if Functions by Taylor Polynomials.
研究問題	What extent did the use of dynamic graphics help the students develop a formal understanding of the limit concept？
研究方法	
教學單元	□數與運算(Number & Operations) ■代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	The limit concept：Approximation and Interpolation.
教育階段	□國小 □國中 ■高中 Eleventh grade high school students.
融入教學之工具	Computer Algebra System
學習活動 (Learning activity)	教學策略： The students used animations in two different ways: 1.Using animations demonstrated by the teacher The students were required to describe what they see in the dynamic picture. In order to do so they had to understand the sensible way in which the static pictures were related ti each other. The students were also asked to understand the syntax of the animations and to translate visual picture to analytical language. 1.1 Visual confirmation of the results obtained by computations of the approximating polynomials. 1.2 View of the dynamic process of convergence as a general property. 1.3 Computational reasoning to clarify the visual illusion of "completing" the ongoing process of convergence. 1.4 Algorithmic reasoning in building the animation's commands that illustrate the convergence process. 2.Building new animations The students tried different examples. They changed the value of the parameter of the animation. In the case of animation on the domain, the aim was to learn about the global behaviour of given function f(x) when x tends to 0. The purpose was to enable the students to visualize the process described by the formal definition of the limit concept. 2.1 The class discussion 2.2 Tami's Mathematicas files
所收集之研究資料	Students' questions and remarks during the sessions、The Mathematica files of the students' examples、Written tests without the use of Mathematica.
研究結果	Computer Algebra System help students reconstruct math concepts and have new learn experiments. That help students to learn.
科技工具之特點	1. In the discussion the students used the dynamic graphical feedback to try other examples and to understand the surprising effect. It enable the students to overcome the misconception mentioned. 2. The students interacted also with the dynamic graphics, generating and exploring, reflecting, and revising. They acted on the dynamic

	representation like changing parameters, choosing other functions and changing the commands. In this way, the students tried to have some control over the dynamic representations.

編號:6060

Data Extraction Form	
欄位名稱	內容
文獻來源	Tsuei, M. (2012). Using synchronous peer tutoring system to promote elementary students' learning in mathematics. Computers & Education, 58(4), 1171-1182.
研究目的	This study was aimed to explore the effects of the synchronous peer tutoring system on children's mathematics learning.
研究問題	1.What are the effects of the G-Math peer tutoring strategy on students' mathematical learning? 2. What are the effects of the G-Math peer tutoring system on self-concept and attitude toward mathematical learning? 3. What are the associations between students' characteristics and learning outcomes in the online peer tutoring environment? 4. What are the associations between students' characteristics and math reasoning skills? And, what is the effect of grouping students with differing abilities on math reasoning skills?
研究方法	A quasi-experimental design, two classes were assigned to the experimental group and one class was assigned as the control group. There were three math sessions (40 min each) per week. In the first two sessions each week, students in both the experimental and control groups received whole class instructions. In the third session, students in the control group worked face-to-face in dyads using the collaborative learning strategy, while students in the experimental group worked in dyads online using the G-Math system in the computer lab.
教學單元	■數與運算(Number & Operations) □代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	加法與減法
教育階段	■國小 □國中 □高中 Eighty-eight children (aged 10–11 years) from three classes in an elementary school in Taipei, Taiwan participated in the study for two semesters from the spring semester of third grade to the fall semester of fourth grade in 2009.
融入教學之工具	This paper proposed the multi-user G-Math Peer Tutoring System (G-Math) and investigated the effects on children's mathematics learning in face-to-face CSCL environment.
學習活動 (Learning activity)	教學策略: Peer tutoring strategy in the CSCL mechanisms. Computer-supported collaborative learning (CSCL)
	The experimental group: Students were paired randomly by the G-Math learning activities management system every other week. The teachers also used the Mathematics Tutoring Activities Module to add math problems according to the lesson for the week. A role-rotation strategy was used. Students alternated between taking on the role of tutor and tutee. When the tutor pressed the "next question" button, the G-Math randomly selected one question from the item bank database. The tutor used the objects and symbols to solve the problem and post the answer in the tutoring area. Next, the tutor assigned the next problem to the tutee to solve by clicking the tutee's avatar. The students were given the opportunity to use various communication and scaffolding tools. They were able to discuss their answers face-to-face as needed. The peer-rating system and experience value mechanism were used when a student solved a problem completely. The teacher observed student tutoring behaviors and corrected misconceptions as needed.

	The control group: Teachers assigned students to pairs and distributed a math problem booklet to each pair, according to the lesson for the week. Students worked in pairs to solve math problems for 30 min. During the last 10 min of a section, the teacher asked students to explain their answers to the class.
所收集之 研究資料	The web-based CBM (ECBM)、The Self-Concept Scale for Children、questionnaire、semi-structured interview.
研究結果	The results indicated that the longer the vulnerable pupils engaged in peer tutoring online, the more they benefited from the process. The finding suggests that students demonstrate different mathematics reasoning skills when they are paired with peers at different levels of ability. These findings demonstrate that the synchronous peer tutoring system is an effective tool to enhance elementary students' learning in mathematics, as well as promote positive self-concepts. 1. Longitudinal changes in math learning: The results indicated that AA and LA students in the GMath experimental group showed a significantly greater increase in CBM scores as compared to AA and LA students in the control group. 2. Performance of students in the G-Math system: Indicate that students gradually performed faster to solve the application and concept problems in both semesters. It appears, therefore, that students decreased manipulation of objects as they became more comfortable with the peer tutoring strategy. 3. Assessment of students' self-concept and attitude toward mathematics learning: Students in the G-Math group indicated higher intrinsic goal motivation than the control group. Self-efficacy however, did not differ significantly between the G-Math and the control group. This result may be due to the belief held by G-Math students that the increase in achievement scores relied entirely on the teacher's instructions. Examples of frequently cited reasons for an enhancement of attitude toward math learning brought about by the G-Math system included: (1) the use of math objects provided by the system to explain the problem-solving process, especially on the application problems, (2) G-Math offers a different and interesting way of learning mathematics, (3) the peer learning process leads to an increase in thinking about why and how to solve problems and (4) G-Math aids in problem-solving strategy recall when taking paper-and-pencil tests. 4. Associations with changes: These clusters were labeled "quick responders" and "slower learners". Quick responders scored higher on the baseline achievement test, self-concept test, and attitude toward mathematics learning and were faster at solving online math problems than the slower learners. The "slower learners" showed a higher growth rate in mathematics learning compared to the "quick responders. 5. Effects on mathematic reasoning skills: These results indicate that most of the students were at the second level of math reasoning skills (the procedure argument level). Students' mathematics reasoning skills correlated significantly with increased scores in self-concept and attitude toward mathematics learning. The results of ANOVA analysis indicated that there was a significant difference in mathematics reasoning skills when students were paired with different ability peers. Students participating in the G-Math group showed significantly greater increases in overall math scores, especially in arithmetic and application problems, and significantly greater increases in self-concept and intrinsic goal orientation than students in the face-to-face control condition.

科技工具之特點	1. The G-Math peer tutoring environment provides a context in which students can practice mathematics while engaged in cognitive construction and sharing. The online reciprocal peer tutoring setting provides students with a synchronous problem-solving process to facilitate students' learning. 2. Online peer tutoring is an effective strategy for helping students increase math learning. In light of the persistent difficulty some students demonstrate in mathematics, our findings are notable. They suggested that the online peer tutoring is one effective strategy for getting these children off to a strong start.The G-Math peer tutoring system provides various communication and scaffolding tools to facilitate tutoring strategies in mathematics peer learning. The tools are located at the bottom of the screen. Students may communicate with each other on the chatting area by typing or face-to-face discussion. 3. The G-Math system provided various CSCL tools for the facilitation of tutoring strategies in mathematics learning including math objects, guiding sentences, a peer-rating system, feedback, and reward mechanisms. G-Math provided thirteen categories of 220 math learning objects for children to manipulate (e.g. symbols, integer concepts and operations, fractions, and pencil tools). Guiding sentences were provided in order to enhance participation and question-posing skills. Feedback was provided by emoticons, a peer-rating system, and an experience value mechanism. The experience values mechanism was based on the number of correct math questions that students solve online. 4. The G-Math system provided students with guiding sentences in the chatting area for peer-instruction. The guiding sentences are frequently-used sentences such as "this is a very import step for solving this problem." or "I do not understand your answers, please show me again." These features were included in the program to help with typing speed and reduce errors at the elementary student level. 5. The emoticons are also designed for enhancing online interactions during peer tutoring activities .When students choose an emoticons, it is displayed on the right side of their avatar. 6. G-Math provides the correct answer for student reflection on their solutions after peer-rating to encourage metacognitive thinking. Experience value and expert level modules were designed to provide a "game-like" atmosphere in the G-Math system. These features were also created to enhance motivation. Students gain one point of experience value when they solve a problem correctly. Five experience values lead to an increase in expert level. The G-Math system uses different images to correspond to experience levels which are displayed beside the student's avatar.

編號:6066

Data Extraction Form	
欄位名稱	內容
文獻來源	Kynigos,C. and Latsi, M. (2006) Vectors in use in a 3D Juggling Game Simulation, International Journal for Technology in Mathematics Education, 13(1), 3-10.
研究目的	In our study we were we were interested to see what meanings our students would generate through the use of the game and their collaborative discussions in their attempt to explain what was happening. The aim of this research project was to understand the interactions between the intuitive, the formal and the procedural aspects concerning vectors in the process of playing the "Juggler game".
研究問題	
研究方法	In our analysis we used a design-based research method (Cobb & all, 2003) which entailed the'engineering' of tools and task, as well as the systematic study of the forms of learning that took place within the specific context defined by the means of supporting it. Initially the aim was to develop the software and the task in order to improve the educational process and to bring about new forms of learning, based on prior research and our theoretical framework. In retrospect research method aims both at improving the initial design and at resulting in a situated understanding of the relationship among theory, designed artifacts and practice.
教學單元	□數與運算(Number & Operations) □代數(Algebra) □幾何(Geometry) ■測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	Vectors
教育階段	□國小 ■國中 □高中 A high school in Athens. In total eight 13 year- old students.
融入教學之工具	Juggler game: Could be considered a micro-world
學習活動 (Learning activity)	教學策略: Our approach in studying students' learning integrates constructionist , and socio-cultural approaches. Students construct their knowledge and understanding of the world not just through direct personal experience and discovery, but also through the intellectual sharing, challenge and support of those around them.
	In particular here we have focused on the way children manipulated and understood vectors and their properties while playing with a ball in the hands of the juggler in the framework of the given task in groups of two. Students could control vectors as well as the hands of the juggler in the 3D space using specific buttons of the keyboard. The micro-world shows an icon of a green vector for the ball's velocity (the resultant) and three red vectors, each signifying the vector's projection on the 3 axes. The students could manipulate the green vector by means of the arrow buttons and observe all the vectors changing accordingly. Moreover an excel spreadsheet was at their disposal with the values of time, X, Y, Z position, velocity and its components in the X, Y, Z axes. Once the run button was pushed, measurements of the above quantities in small constant time intervals appeared on the excel sheet. The students could thus use the vector icon both to control the velocity of the ball and to observe the changes of the vector as the ball volleyed during the running of the game.
所收集之研究資料	A team of two researchers participated in each data collection session using one camera and two tape-recorders.
研究結果	In the 'Juggler' micro-world students generated and used visualizations about the properties of vectors, interpreting the visual aspects by means

	of notions abstracted within specific situations involving playing of the game. It seems that in the context of this computer game students gradually discriminated some properties of vectors, they controlled them in a dynamic, kinesthetic way and they were able to form conjectures about the ball's trace. After a few trial and error attempts students appreciated the importance of the resultant of velocity and its determinative effects on the ball's trace, as well as the fact that it was the composition of the three other vectors. However they had difficulties or were uncertain about the role of arrows that represented the velocity's components. Taking into account that students are not yet encultured in the scientific vocabulary and that they don't have the formal, analytic tools to be systematic and specific, it could be pointed out that their comments and their figurativeness were quite insightful and indicative of their progressive awareness of the components' properties.
科技工具之特點	1. It offers multiple 3D external representations, analogical to some aspect of the physical world. 2. Students can dynamically control the vectorial representation of velocity through manipulation of keyboard buttons or use logo-programming so as to control the simulation, to question the laws of motion or the behaviour of the moving agents by changing the respective code in the program.

編號:6098

Data Extraction Form	
欄位名稱	內容
文獻來源	McLeod, J., Vasinda, S. & Dondlinger, M.J. (2012). Conceptual Visibility and Virtual Dynamics in Technology-scaffolded Learning Environments for Conceptual Knowledge of Mathematics. Journal of Computers in Mathematics and Science Teaching, 31(3), 283-310.
研究目的	This study consider achievement a baseline and evaluated the manipulatives from the perspective of the student, examining aspects of the virtual manipulatives that led to self-regulated learning behaviors, discovery and learning of the underlying mathematical concepts under study, constructive emotional connections to learning and more.
研究問題	One research question from that qualitative case study examined students' conceptual knowledge building when using these five virtual manipulatives.
研究方法	Qualitative case study. Semi-structured interviews in which students were asked to describe their learning with the manipulatives, including what drew them into the work and how and why they continued to explore and learn when the work was complex or challenging
教學單元	■數與運算(Number & Operations) □代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	Proportional thinking
教育階層	■國小□國中 □高中 Sixth grade students at a Title I elementary school in a North Texas suburban town
融入教學之工具	five different virtual manipulatives from four different websites
學習活動 (Learning activity)	教學策略:
	1.first week： (1)students were beginning to learn ratios and proportions, a new concept in sixth grade that builds upon past learning of fractional and decimal equivalents. After demonstrating an understanding of ratios, students moved to conceptual understanding of proportions as two equivalent ratios using the virtual manipulative displayed。 (2)During their interaction with these virtual manipulatives, students connected proportions with photography and decided whether a targeted ratio or enlarged photograph was equivalent to the original ratio or original photograph. This manipulative includes a multiplier across the top of the workspace which connects the students to the mathematics necessary to decide whether ratios are proportional. Students also received visual mathematical feedback when they clicked a multiplier and the outline of the photograph responded. Duringthe interviews, this work was called "Resizing Images."Once students conceptually understood the definition of a proportion, the next virtual manipulative assisted students in building a model of using proportions to solve for an unknown. MathPlayground.com hosts the Thinking Blocks manipulative for this work. The manipulative first presents students with a problem and prompts them to build a model of the ratio that they then label and use to solve the problem. 2.second week： (1)students learned about percents as a ratio and also modeled percent, decimal and fractional equivalents. To help students develop a mental model of a percent, the teacher used the virtual manipulative 。 (2)Students were presented with a blank ten by ten grid and the manipulative asked students to model a certain percent and provided

	feedback on their answers. (3)During the interviews, this work was called “Percent Grid.” This same grid with 100 squares was used throughout the week to continue to develop and reinforce students’ conceptual knowledge of a percent. (4)After students gained an understanding of a percent, they needed to incorporate this understanding into their existing knowledge of decimals and fractions. Earlier in the year, students had studied decimal and fractional equivalents and built mental models of those concepts. For this work, students used the NLVM manipulative for representing decimals. This manipulative offered students random decimals that they modeled. Then, they sketched the model of the decimal along with the percent model using the hundreds grid. They also wrote the decimal and the percent. 3. Finally, students incorporated their models of fractions into their new percent knowledge using a virtual manipulative on Shodor.org. Students were presented with a fraction. They then used the next blank box to create their percent grid by making 10 rows and 10 columns. As they shade their percent model, the arrow on the number line moved to offer mathematical feedback as to the size of the model they created. Once students had an equivalency match between the fraction and the percent models, they documented their work by sketching their results on paper.
所收集之 研究資料	student interviews：students were asked to describe their learning with the manipulatives, including what drew them into the work and how and why they continued to explore and learn when the work was complex or challenging.
研究結果	質性:資料編碼後有四個發現 1.Self-regulation: Seemed to have a positive effect on learners’ self-regulatory behaviors. 2.Discovery & Learning: Ultimately their discovery and learning. 3.Digital tools: Students were using to help construct that knowledge. This coupling indicate to us that building conceptual knowledge requires multiple and varied opportunities for learners to test hypotheses and continue to reshape their mental models. 4.Emotional Connections: Some virtual manipulatives fostered positive emotional connections to learning.
科技工具之特點	1. Technology-based Scaffolds： (1)visual modeling：benefits of “seeing” the mathematical concept or model using visual vocabulary in their statements. When students adopted the stance that tasks can be completed more easily, quickly and efficiently if they use technology to complete it or described technology as compelling, authentic or realistic (2) material intelligence：material intelligence means that “thinking, problem solving and knowledge are ‘stored’ in material objects and the environment. This frees learners to engage their minds with other things while combining the results of their own thinking with the knowledge stored in material objects and the environment to achieve yet more powerful effects. (1)(2): Allowed students to explore the limits of the mathematical concept and provided important mathematical feedback to students along the way；scaffolds embedded into the environment did not necessarily provide mathematical feedback, but offered students clues as to how to proceed or to solve. The up arrow button on the percent grid manipulative and the multiplier button on the resizing images work. (3) amplification of effort ：provided in the resizing images and the

	percent grid manipulatives, which allowed students to explore purposefully and to use their cognitive energy for other learning activities. 2. Visibility of the conceptual metaphor When students stated that a manipulative helped them "see" a mathematical concept, they found that the manipulative helped build their mental models and deepen their understanding of the concept. 3. dynamics of virtual manipulation. The interactive, dynamic nature of a virtual manipulative allows students to see changes in the digital display as they manipulate variables or other input. This dynamic affordance allows them to test their own theories and intuitions and get immediate mathematically based feedback. From this feedback, learners can modify their conceptions, generate new theories, and then test their understanding again. Allowed them to play with the concepts as they learned their limits 4. the virtual manipulatives can enable the discovery of laws and properties. Afforded trial and error which allowed her to proceed even when students were stuck.

編號:6106

Data Extraction Form	
欄位名稱	內容
文獻來源	Suh, J. & Moyer-Packenham, P. (2007). Developing Students' Representational Fluency Using Virtual and Physical Algebra Balances. Journal of Computers in Mathematics and Science Teaching, 26(2), 155-173.
研究目的	students with different algebraic models and encourage students to use informal strategies to represent their relational thinking
研究問題	
研究方法	The project involved two groups of third-grade students in a week-long unit focusing on algebraic relationships.
教學單元	□數與運算(Number & Operations) ■代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	Algebraic relationships(solve simple linear equations)
教育階段	■國小 □國中 □高中 Third-grade students in a week-long unit focusing on algebraic relationships.
融入教學之工具	Virtual manipulatives(Virtual Balance Scale applet on the National Library of Virtual Manipulatives (http://matti.usu.edu/nlvm/nav/)
學習活動 (Learning activity)	教學策略:引導式教學
	1. students were given opportunities to work with multiple representations to build representational fluency. As a class, the teacher and students worked together to show how this problem could be written as an equation .Students were shown simple models of algebraic relationships using arithmetic sentences (i.e., 2 + 3 = 5) on the balance scale. 2. When the teacher introduced the idea of x as the unknown, teacher used a box with an x written on it and placed it over the number 3 to represent the missing addend. She wrote 2 + x = 5 and asked students to determine the value of the unknown. 3. Students had opportunities to translate algebraic expressions into manipulative models. Students using the virtual balance scale set up the algebraic expressions shown on the computer screen and used the blocks to solve for x. And the virtual balance applet helped students represent the written expressions of quantitative relationships using manipulative models.(the link between the symbolic and manipulative representations was more closely tied together in the virtual manipulative environment, because the symbolic expression was on the screen during the process.) 4. Students kept a record of their mathematical procedures using drawings and written expressions. In the virtual manipulatives group, students worked on the problems online and recorded the arithmetic operations on the task sheet while working with the balance scale applet. After several problems, students were asked to print out three screen shots of the work from the virtual applet. 5. Students were asked to verbalize the steps they took to solve the problems. 6. At the end of each lesson the teacher closed with a whole-class discussion that focused on questions such as: (a) What were ome strategies you used to find the value of x? (b) How would you describe he rules for finding the value of x to someone who doesn't know algebra?
所收集之 研究資料	Pretest and posttest、field notes, interviewed students, and videotaped class sessions

研究結果	量化： Result from the pre and posttest measures showed that students in the virtual manipulative environments gained signifi cantly in achievement and showed fl exibility in translating and representing their understanding in multiple representations: manipulative model, pictorial, numeric, and word problems. 質性：(Unique Features of the Representations that Promoted Student Learning) The virtual environment also had unique features that promoted student thinking such as: (a) Explicit linking of visual and symbolic modes (b) Guided step-by-step support in algorithmic processes (c) Immediate feedback and self-checking system.
科技工具之特點	Identify unique features of the learning environments. The virtual environment had unique features that promoted student thinking: 1. Explicit linking of visual and symbolic modes: One of the features of the virtual balance scale was that it explicitly linked a dynamic picture of the balance scale with the symbolic representation of the algebraic equations that were presented on the scale. students typed in a symbolic command such as "subtract 3x from both sides," the dynamic feature of the applet removed three of the x boxes from both sides of the balance scale and simultaneously displayed a new equation on the screen. The equation window tracked moves made by the student, thereby scaffolding the process of solving for x, and explicitly providing the connection between the equations and the actions of the balance scale. During class sessions, when the teacher asked students to explain their solution processes, students were observed using the equation window, which is where these processes had been recorded by the virtual applet 2. Guided step-by-step support in algorithmic processes: Another feature of the virtual balance applet was a built in constraint support system that emphasized the guided, step-by-step process for solving the equations. The balance scale placed an emphasis on subtraction and division as solution routes for balancing the equations. For example, guidance would be given such as, "You can't subtract 4x from both sides unless here are at least 4xs on each side." Because of these features, students were required to choose an operation and perform the operation while the applet displayed each equation during the solution process. Teaching cues were provided to ensure that students performed the procedures accurately. 3. Immediate feedback and self-checking system: Students received immediate feedback while they were solving the problems and were able to use a self-checking feature to determine the accuracy of their solutions. For example, if students made an error, the computer would prompt, "The two sides don't match the equation." This self-checking system kept students from practicing erroneous solution routes and allowed them to check their own answers. Students liked the way the balance scale tilted and balanced based on the equations. They commented, "I like the way the balance scale shows me I have set up the right number sentence by balancing itself. If I don't do it right, one side slants down." The teacher's observational notes also highlighted this feature: "One advantage that I saw with this tool was that the balance scale tilted as blocks were removed. This feature showed students the inequality and equality of an equation by the tilt of the balance scale. Virtual environments were effective in supporting students' learning and encouraging relational thinking and algebraic reasoning.

編號:6134

Data Extraction Form	
欄位名稱	內容
文獻來源	Sedig, K. (2008). From Play to Thoughtful Learning: A Design Strategy to Engage Children With Mathematical Representations. Journal of Computers in Mathematics and Science Teaching, 27(1), 65-101.
研究目的	The purpose of this research is to investigate whether and how games can be designed to help children learn mathematics in an enjoyable and motivating way.
研究問題	
研究方法	A quasi-experimental nonequivalent pretest-posttest group design. G1: AT, using ST + mediation, AT, fi lling out DQ G2: AT, using ST, AT, fi lling out DQ G3: AT, using ST – embellishments, AT, fi lling out DQ G4: AT, no treatment during the period in which other groups used ST,AT
教學單元	□數與運算(Number & Operations) □代數(Algebra) ■幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	Geometry concepts
教育階段	□國小 ■國中 □高中 Upper-middle-class school (students in grade 6)
融入教學之工具	Game(Super Tangrams: is an interactive game designed to initially motivate children (grade 6+) to engage with the environment in a playful fashion and to gradually shift their attention towards nontrivial aspects of two-dimensional transformation geometry concepts through thoughtful engagement with visual representations of these concepts.)
學習活動 (Learning activity)	教學策略：experiential learning environment
	Groups G1, G2, and G3 spent 10 sessions, approximately 40 minutes in length, using the software in pairs, where subjects were paired by the teachers according to any criteria they saw fi t. These sessions were held during school hours when children were scheduled to study mathematics. Subjects would leave their classes and come to the room in which the computers and the software were set up. Each pair of students was assigned a computer to work on. At the beginning of the first session, a researcher gave a brief overview of the goal and rules of the program and how to operate it. During the subsequent sessions, since the program kept a log of the last puzzle the subjects had solved, subjects would continue from the last puzzle in the game that they had solved. During all sessions, a researcher was always present in the room, but no teachers were present. Subjects in group G1 who needed help would raise their hand to receive assistance; the researcher would answer procedural questions related to the operation of the program, but would not provide direct instruction on test-related content. Subjects in groups G2 and G3, however, had to figure things out on their own and were advised that answers to their questions could be found in the program. Group G4 did not know anything about ST and simply continued with their normal school work during the course of the study.
所收集之 研究資料	Two sources of data were used to study the effectiveness of ST and its design: an achievement test and a design questionnaire.
研究結果	1. Overall Achievement Results： That each one of the three treatment groups (mediated, without mediation, and without mediation and embellishments) exhibited improvement after interaction with the learning environment. 2. Analysis of Grouped Questions： There is marked improvement on the posttest. This pattern was repeated

	for all other sets of grouped questions. 3. Motivation Results： These results suggest that being perceived as “full of math” did not have a negative motivational effect on the children. The results of the study suggest that, despite theexplicitness and difficulty of the mathematical concepts involved, children found the learning process fun and engaging. Furthermore, children exhibited significant improvement in their knowledge of transformation geometry concepts.
科技工具之特點	Children need to interact with the visual representations of the transformation concepts. That is, the representations mediate between the children and the game. The representations are transparent, and children do not need to be thoughtful and conscious of their presence.

編號:6140

Data Extraction Form	
欄位名稱	內容
文獻來源	Wu, Y. & Wong, K.Y. (2007). Impact of a Spreadsheet Exploration on Secondary School Students' Understanding of Statistical Graphs. Journal of Computers in Mathematics and Science Teaching, 26(4), 355-385.
研究目的	This case study investigated the impact of a spreadsheet (EXCEL) exploration on the understanding of statistical graphs among twenty Singapore secondary school students of average ability.
研究問題	1. Do secondary school students have a better understanding of statistical graphs after they have worked with EXCEL, which was chosen for this study because it is widely available in Singapore schools? 2. What strategies do these students use when they explore statistical graphs embedded in EXCEL templates?
研究方法	A case study research design is suitable for this exploratory study.
教學單元	□數與運算(Number & Operations) □代數(Algebra) □幾何(Geometry) □測量(Measurement) ■資料分析與機率(Data Analysis & Probability)
教學主題	These four topics were selected: (a) the starting point of a vertical scale in a bar graph, (b) effects of different parameters of the vertical scale on the appearance of a line graph, (c) three-dimensional pictures used to display numerical quantity in a size pictogram, and (d) cumulative line graph.
教育階段	□國小 ■國中 □高中 (Grade 8,9)
融入教學之工具	Spreadsheet (EXCEL): EXCEL template is designed to begin with a realistic problem embedding an error or a misleading situation about statistical graphs. (Templates Template 1: Zero in scale、Template 2: Effect of scale、Template 3: Size pictogram、Template 4: Cumulative line graph.)
學習活動 (Learning activity)	教學策略: Four pedagogical principles were considered for the EXCEL exploration: (a) confronting cognitive conflicts (b) building relationships (c) constructing knowledge (d) learning collaboratively.
	1. templates Template 1: Zero in scale (1) the first worksheet asks students to judge whether or not Mike has twice as many stamps as Jane based on a bar graph whose vertical scale starts from 8 instead of 0. Clicking the No button will show a pop-up question asking for an explanation. The Yes button will show the pop-up question asking students to read from the graph the number of stamps Mike and Jane had, to alert them to a conflict between the graphical features (G, heights of bar graphs) and the numerical values (N, number of stamps). (2) the second worksheet, students enter values for Maximum, Minimum, and Unit to arrive at a suitable vertical scale for the given data. (3)In the third worksheet, they complete the same task involving a larger collection of stamps. 2.Template 2: Effect of scale Requires students to explore how different parameters of the scale of the vertical axis affect the appearance of a line graph (G) and the meaning conveyed(M), in this case, little or drastic changes in the temperatures given(N). (1) Worksheet 1 presents two line graphs of the same data with different

	scales. Students are asked to judge whether the temperature patterns shown in these two line graphs are the same or different. Placing the two graphs side by side provides a conflict that the students have to resolve (2) worksheet 2, they explore the effects of different values for maximum, minimum, and unit on the appearance of the line graph. (3) Worksheet 3 requires students to check the scale used in a line graph to depict a new context 3.Template 3: Size pictogram Addresses the common misuse of size pictogram when the reader is led to focus on the volume conveyed by a graphic rather than its linear dimension. (1)worksheet 1, a number pictogram and a size pictogram are given, and students are asked to judge whether each pictogram has represented the data correctly, thus creating potential cognitive conflicts (2) worksheet 2, students are directed to take note of the side and the volume of the two cubes and reconsider whether or not the size pictogram is correct. (3) worksheet 3, students are to construct a correct size pictogram by relating the graphical feature (G, volume of a cube) to the numerical value it is supposed to represent (N, sales of cereal). 4.Template 4: Cumulative line graph Creates a conflict when students interpret a cumulative line graph as a normal line graph if they do not pay attention to the stated context of "the total number of books sold from Monday morning up to the end of each day." To resolve this conflict, the students need to link the graphical feature(G, increasing trend) to the number of books sold (N) in terms of the underlying concept of cumulative frequency (M). (1)Worksheet 1：find out students' interpretation of the cumulative line graph, where numerical values are not given in the graph. (2)Worksheet 2 requires students to enter the number of books sold in each day until they arrive at a graph that matches the given cumulative line graph.
所收集之 研究資料	1. Observation of students' interactions with the EXCEL templates by the first researcher who took field notes of these sessions. 2. The students were encouraged to talk aloud when they worked on the EXCEL templates and these dialogues were audiotaped and transcribed. 3. Students' online work was recorded using macros and saved as computer files. These files were played back later, and the findings checked against the field notes and audiotapes. 4. Pre and post-TUSG. This provides a measure of quantitative changes in students' understanding of statistical graphs.
研究結果	Three quarters of the students showed gain scores in the posttest, suggesting positive impacts of this exploration on students' understanding of statistical graphs.
科技工具之特點	1. Instant and accurate calculation. 2. Powerful capability in constructing different types of statistical graphs. 3. Students had focused on graphical features that led them to arrive at trivial conclusions. Those who arrive at trivial conclusions will then be able to move in the right direction. Having students present their findings to the whole class will also help them develop communication skills to explain their work to others. 4. Dynamic link between data and graphs understanding statistical graphs is to be able to establish meaningful connections between graphical features, numerical values of the data, and the meaning related to the context of the graphs. Understanding statistical graphs is to be able to establish meaningful connections between graphical features, numerical values of the data, and the meaning related to the context of the graphs.

	5. Macro programming. Students can give fuller attention to making sense of the screen output and relating it to the desired learning objectives. 6. The interactive feature of EXCEL allows the students to self-check their responses.

編號:6155

Data Extraction Form	
欄位名稱	內容
文獻來源	Moyer-Packenham, P. & Suh, J. (2012). Learning Mathematics with Technology: The Influence of Virtual Manipulatives on Different Achievement Groups. Journal of Computers in Mathematics and Science Teaching, 31(1), 39-59.
研究目的	This study examined the influence of virtual manipulatives on different achievement groups during a teaching experiment in four fifth-grade classrooms.
研究問題	1. How does the use of virtual manipulative fraction applets during a unit on fraction addition and equivalence influence students'mathematics achievement for students of different achievement levels? 2. What are the effects on average achieving students during a unit on fraction addition and equivalence for students who use the virtual manipulative fraction applets and those who do not? 3. How do the virtual manipulatives influence the way that students of different achievement levels experience the learning of fraction addition and equivalence?
研究方法	One low achieving, two average achieving, and One high achieving group participated in two instructional treatments (three groups used virtual manipulatives and one group used physical manipulatives).
教學單元	■數與運算(Number & Operations) □代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	Two rational number concepts (fraction equivalence and fraction addition with unlike denominators)
教育階段	■國小 □國中 □高中 Fifth-grade classrooms.
融入教學之工具	Virtual manipulatives applets. (From the National Library of Virtual Manipulatives website (www.nlvm.usu.edu) and the National Council of Teachers of Mathematics electronic resources (www.nctm.org))
學習活動 (Learning activity)	教學策略: 1. Lessons in the computer lab began with an introduction to the virtual manipulative applet; this was followed by several mathematical tasks for the students to complete independently. 2. Each day, students received teacher made task sheets with instructions for using the virtual manipulatives and space to record their work. 3. The teacher modeled how to use the virtual manipulative applets before students worked independently. 4. Lessons in the regular classroom began with an introduction to the mathematics topic for the day; this was followed by several mathematical tasks where students used physical manipulatives. Students completed worksheets and teacher-made task sheets that provided practice with the physical manipulatives. 5. At the end of each computer lab and classroom session, the teacher used the last 10 minutes of the class to hold a discussion with the students to elicit thinking and connect ideas that students explored during the sessions.
所收集之研究資料	Pre- and post-tests of students' mathematical content knowledge and videotapes of classroom sessions.
研究結果	一、量化： 1. There was a significant gain overall for the students participating in the virtual manipulatives treatment. The low achieving students benefited most from their participation in the virtual manipulatives treatment, with

	statistically significant gains as an individual group. 2.There were no significant differences between the average achieving student groups in the virtual manipulatives and physical manipulatives treatments. 二、質性： 1.indicated that the different achievement groups experienced the virtual manipulatives in different ways: ＊The high achieving group： recognizing patterns quickly and transitioning to the use of symbols ＊The average and low achieving groups： relied heavily on pictorial representations as they methodically worked step-by-step through processes and procedures with mathematical symbols. 【Day 1】Fractions–equivalent and fractions–visualizing applets. All achievement groups contained several students who explored with the applet to determine how many pieces they could break apart each region on the applet. Once one student began this exploration, other students around the student also wanted to see how many pieces they could make with the applet. ＊The high achieving group：creating multiple visual images of the fraction representations rapidly, going beyond the applet requirement of finding only two equivalent fractions. students quickly recognized numerical relationships among the numerators and denominators of the equivalent fractions, and no longer needed to manipulate the fraction regions to find an equivalent fraction; they could create the equivalent fraction using mental math. ＊The average and low achieving groups：use the region models as support to find equivalent fractions throughout the tasks. They relied more on the visual aspects of the applet and used counting strategies, rather than recognizing the proportional relationships. 【Day 2】: Fractions–comparing applet. ＊The high achieving group: used their knowledge of multiples and numerical relationships to determine common denominators to compare the two given fractions on the applet. ＊The average and low achieving groups：slower and more methodical as they clicked through the possible choices of multiples on the applet to find a common denominator. the average students： knew the multiples, but they used the applet to confirm their thinking. They appeared less confident of their knowledge of the multiples. The applet directions ask students to “find different names” for the two fractions that are given in order to compare the two fractions. The low achieving group：observed finding equivalent fractions to the given fractions, but not common denominators. 【Days 3 and 4】Fractions–adding applet. All groups were influenced by the built in constraints in the applet that did not allow students to add the two fractions together until they renamed each fraction using a common denominator. ＊High achieving students： quickly the addition procedure and provided guidance and immediate feedback that confirmed that students were following the procedures on the applet. Students did not need the visual models to find an equivalent fraction, so they simply entered in the numbers on the applet. They also did not need to move the fraction pieces on the applet to the sum circle or square because they quickly observed the sum of the two fractions without employing this step. ＊The average achieving students：developed some efficiency strategies. they were observed writing multiples of given denominators on their task sheets or typing in the numbers for common denominators on the applet first and then using the applet models to check their thinking

	＊The low achieving students：engaged in multiple trial and error interactions. They entered multiple wrong answers into the applet and through guidance and feedback provided by the applet, the low achieving students experimented until they understood the addition procedure. they could not use these equivalent fractions in the applet because of the built-in constraints. This individual struggle seemed to help them learn the procedure for finding the common denominator. This trial and error process helped the low achieving students learn the procedures at their own pace. 【Day 5】 Fraction track game. There were observable differences among the groups. ＊The high and average achieving groups: recognized the equivalent fractions and could u se this knowledge to be strategic in the game. Not only did they recognize the amount they had on the number line in the applet, but they also recognized the amount that remained (the residual) to get to one whole. Both groups used some mental addition and subtraction strategies. ＊The low achieving students：did not connect their work with equivalent fractions to the activities in the game.The low achievers often filled up each line on the board and then waited to get the exact remaining amount (rather than using an equivalent amount);they did not know what to do when they got a number that did not complete any of their remaining lines on the game board. ＊The high achieving group: used more mental math strategies, identified multiples and factors, saw patterns more quickly, sometimes ignored the pictorial models in the applets, recognized equivalence and proportional relationships, applied equivalence understanding to use as a strategy in the fraction game, and focused on symbolic features in the applets to complete mathematical tasks. ＊The average achieving group: used some mental math strategies later in the fraction unit, used a step-by-step methodical process to find/check multiples and common denominators, relied on the pictorial models in the applets, used counting strategies rather than proportional relationships, recognized equivalence relationships later in the fraction unit, applied equivalence understanding to use as a strategy in the fraction game, and relied on pictorial and symbolic features in the applets to complete mathematical tasks. ＊The low achieving group used a step-by-step methodical process to find multiples and common denominators, relied heavily on the pictorial models in the applets, used counting strategies rather than proportional relationships, did not recognize equivalence relationships, experienced confusion with common denominators, and engaged in multiple trial and error interactions with the pictorial and symbolic features in the applets to complete mathematical tasks.
科技工具之特點	1. Efficient precision: the virtual manipulatives contain precise representations allowing accurate and efficient use. This affordance seemed to be most influential and beneficial for the high achieving students. The high achieving groups were able to recognize patterns quickly and then proceeded to skip or ignore pictorial and guiding features in the applets. The applets contained efficiency features that allowed the user to quickly produce multiple examples or to skip elements within the applet (e.g., students did not need to use the pictorial elements to get the numerical elements correct). The applets allowed the high achieving students to learn the mathematical concepts and processes, see patterns and relationships, and use the virtual manipulatives with efficiency. 2. Focused constraint：in which the virtual manipulatives constrain student attention on mathematical objects and processes, seemed to be

	most influential and beneficial for the average and low achieving students. The average and low achieving students used multiple trial-and-error attempts to determine common denominators and to find common denominators so that they could add two fractions together. The constraining, guiding, and feedback features supported the low and average achievement groups throughout their mathematical interactions. The guiding and support features were available to students as long as these support features were needed. This was especially evident for the average achieving students, who seemed to rely on the pictorial and symbolic models initially, and during later class sessions, they did not need this pictorial support at the same level as they had on Days 1 and 2. A constraint-support structure in a virtual environment "frees the student to focus on the connections between the actions on the two systems [notation and visuals], actions which otherwise have a tendency to consume all of the student's cognitive resources even before translation can be carried out". The high achieving students were freed to focus on the connections and relationships, which they did rapidly, while the average and low achieving students received sustained support from the constraints in the applets throughout the fraction lessons. The methodical trial and error activity of the low and average achieving students provided multiple examples that students could work through at their own pace. 3. Applets may provide higher achieving students with multiple examples so that they can quickly recognize patterns, while other applets can provide constraints and guiding feedback for lower achieving students who need more support and guidance. In addition, there are virtual manipulative applets that contain multiple affordances. 4.The multiple affordances built in to the virtual manipulatives provide "something for everyone" and a way for students at each achievement level to learn the mathematical concepts and procedures. The different impacts on students of different achievement levels may be a factor that is important for the design of mathematics instruction that uses technology. These different effects may have been caused by the visual/pictorial models that helped students to understand the concepts. Or students may have been helped by the pictorial models being linked with the mathematical symbols so that they saw two different forms of representation while students were working 5. The virtual manipulatives also provided opportunities to practice using a visual model that could be changed and manipulated.

編號:6157

Data Extraction Form	
欄位名稱	內容
文獻來源	Suh, J.M. (2010). Leveraging cognitive technology tools to expand opportunities for critical thinking on data analysis and probability in elementary classrooms. Journal of Computers in Mathematics and Science Teaching 29(3), 289-302.
研究目的	The focus of the present study was to examine and describe the process of designing mathematical tasks which used technology to both expand access and provide opportunities to elicit critical thinking and reasoning with diverse learners.
研究問題	1. What affordances exist in a technology-filled learning environment that promote mathematical thinking? 2. What mathematical processes become amplified by the use of technology tools?
研究方法	Case studies. Case Study 1: Teaching and Learning Data Analysis Using Technology. Case Study 2: Probability Experiments Via Technology Tools.
教學單元	□數與運算(Number & Operations) □代數(Algebra) □幾何(Geometry) □測量(Measurement) ■資料分析與機率(Data Analysis & Probability)
教學主題	Data analysis and probability concepts. Case study 1: Statistical data to understand mean, median and mode. Case study 2: The initial recognition of the nature of random processes、the exploration of the concept of chance through games and experiments、the comparison of the likelihood of theoretical and experimental events.
教育階段	■國小 □國中 □高中 Fifth grade at a Title I elementary school
融入教學之工具	虛擬教具(from the National Library of Virtual Manipulatives (http://nlvm.usu.edu/)
學習活動 (Learning activity)	教學策略:
	Case study 1 In a 5th grade classroom, students experimented with statistical data to understand mean, median and mode. To begin the lesson, the class collected information about the number of letters in their names. Their initial data showed that their results ranged from 3 to 11. The class used the box plot applet from the National Library of Virtual Manipulatives (http://nlvm.usu.edu/) to record their data and then discussed the various aspects of the box plot and the measures of central tendency that were displayed on the screen. The mean appeared as 5.41. A quick glance at the data chart showed that 5 was the mode. The box also indicated that the 50% of the class names were between 4 and 6 by looking at the lower and upper quartiles. Based on this information, students agreed that the best way to measure the central tendency was to use the mode of 5 since having 5.41 letters was not logical. After interpreting and discussing the results of the box plot, the teacher posed the following problem. Students began to think critically about the relationships between each point of data and the mean, median, and mode. After allowing students to make conjectures and list their ideas on the board, one of the students entered the number 50 into the data set and clicked the UPDATE BOXPLOT button. Students looked intently at the new box plot and confirmed and refuted their prior conjectures. The discussion led to the extremely important idea of what happens with the presence of outliers; a term introduced after much discussion about the "extreme number". Students engaged in a lively discussion about which was a better measure of

	tendency when extreme outliers were present. Many students stated that the new mean, which was 7.2, was misleading since 50% of the data centered around 4 and 6. Additionally, students agreed that the mode of 5 and the median were the measures of central tendency that best represented the data. Case study 2 A 5th grade classroom studying the concept of probability engaged in an experimentation using handmade spinners and virtual spinners. The class activity was called “Mystery Spinners”, ten spinners were distributed, one to each pair of students. Students were asked to independently look at their spinners, predict the outcome, spin their spinner 30 times and finally record the results as a bar graph. Once the teams of students finished conducting their experiment, their bar graphs were displayed for all to see. The teacher then mixed up the ten spinners and posted them on the board. Students were challenged to match the spinners displayed on the board with the bar graph that they thought was the most likely outcome of the spinner. In the case of many of the spinners, students were able to make accurate matches. However, two spinners resulted in similar outcomes in which each of three colors, green, blue and red had approximately equal amounts. Students argued that spinner A should have had 25% (7 or 8 out of 30) red, 25% blue (7 or 8 out of 30), and 50% green (15 out of 30) because it was ¼ red and ¼ blue and ½ green. The students also felt that spinner B should have had 33.3% red (about 10/30), 33.3% (10/30) blue and 33.3% (10/30) green since it was 1/3 red, 1/3 blue and 1/3 green. This led to a great discussion about theoretical and experimental probability. The next day, students went to the computer lab and were introduced to the adjustable spinner applet from NCTM’s Illuminations website. Through experimentations, students were able to see that with a minute number of trials, an individual could be easily misled as to the composition of the spinner; as in the following illustration with only 10 spins.
所收集之 研究資料	The analysis of students work, the researcher’s memos and narrative reports from the teachers.
研究結果	1.Specific opportunities that technology rich mathematics environments afford teachers and students are the abilities to: (1) build representational fluency by making connections among multiple representations (2) experiment and test out conjectures which efficiently develop reasoning and proof (3) facilitate the communication of mathematical ideas through problem solving. 2. The technology “enforced the mathematical rule of behavior” of the mathematical concept of the law of large numbers. By setting the technology function to take larger trials into consideration, students were able to see how the experimental graph became more like the theoretical graph. These tasks were specifically designed to provide students opportunities to draw logical conclusions and justify both answers and solution processes by explaining why, as well as how they were achieved.
科技工具之特點	1. The ease of representing different box plots with such efficiency allows for a higher mathematical complexity than merely creating box plots. With the use of technology tools, an increased amount of experimentations and additional time for deeper analysis are incorporated into the learning environment. 2. The technology affordances of the spinner applet amplified the mathematical learning opportunities available by allowing the students the ability to adjust the number of spins, to create, and test conjectures, and also appreciate the power of the law of large numbers.

	3. Technology applets with dynamic objects and visual tools offer learners multiple representations to consider while learning mathematical concepts. The dynamic spinner "enforced the mathematical rule of behavior" of the mathematical concept 4. Students were able to see how the experimental graph became more like the theoretical graph. These tasks were specifically designed to provide students opportunities to draw logical conclusions and justify both answers and solution processes by explaining why, as well as how they were achieved. 5. The ability to manipulate the data to see how the mean, median and mode were affected allowed for students to gain a deeper understanding of and differentiate among the central measures of tendency.

編號:6158

Data Extraction Form

欄位	內容
文獻來源	Bolyard, J. & Moyer-Packenham, P. (2012). Making Sense of Integer Arithmetic: The Effect of Using Virtual Manipulatives on Students' Representational Fluency. Journal of Computers in Mathematics and Science Teaching, 31(2), 93-113.
Aim(研究目的)	investigated how the use of virtual manipulatives, representing two different models for integers,impacts student achievement for integer addition and subtraction. Also of interest in this study was the influence of virtual manipulatives on students' ability to create and translate among representations for integer addition and subtraction.
研究問題	1. Integer addition and subtraction impact students' achievement in computation? 2. Are there differences in achievement among the three treatment groups using each web-based virtual manipulative? 3. How does the use of web-based virtual manipulatives for integer addition and subtraction influence students' creation of and translation among representations during task solutions?
研究方法(Method)	1.Quasi-experimental pretest-posttest design. 2.Six classes (99 人) were randomly assigned to one of three treatment groups: Virtual Integer Chips (VIC), Virtual Integer Chips with Context (VICC), and Virtual Number Line (VNL).
教學單元	■數與運算(Number & Operations) □代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	Addition and subtraction of integers.
教育階段	□國小 ■國中 □高中 Ninety-nine sixth-grade students participated two public middle schools
融入教學之工具(Tool)	Virtual manipulatives (web-based virtual manipulatives: Virtual Integer Chips (VIC), Virtual Integer Chip with Context VICC), and Virtual Number Line (VNL).)
學習活動(Learning activity)	1. Instructional activities using the VNL model used the metaphor of walking along a line a specified number of spaces in the direction indicated. Instructional activities using the VIC and VICC models employed the metaphor of debts and assets. These metaphors were used during all classroom discourse as well as on all instructional handouts. 2. During instruction, introductory activities focused on establishing the respective metaphor using related physical and pictorial models. 3. Students also participated in extended computer lab sessions (30 to 40 minutes) in which they used the virtual manipulatives to explore integer addition and subtraction. 4.Following each computer session, students engaged in follow up discussions focused on articulating their observations.
所收集之研究資料	Integer addition and subtraction pretests and posttests and student interviews.
研究結果	Students increased in integer computation achievement and demonstrated facility with pictures and written representations. 一、量化: 1.All treatment groups showed a significant increase in student achievement. 2.There were no significant differences among the groups for addition or subtraction 二、質性：(How does the use of web based virtual manipulatives for integer addition and subtraction influence)

	1.Analysis of Students' Work with Representational Forms for Integer Computation：These interviews revealed that students were generally able to work flexibly within the written/metaphorical and picture representational forms for integer addition and subtraction. 2.Facility with Representational Forms: Pictures and Written/Metaphorical：Students were successful in evaluating integer addition and subtraction items presented in written/metaphorical and picture representational forms. Further, the students were generally successful in translating items to written/metaphorical and picture forms. (1) Students demonstrated significant gains in computation achievement after using three different virtual manipulative applets during instruction of integer addition and integer subtraction concepts. (2) There were no statistically significant differences in achievement among students using three different virtual manipulative applets designed for integer instruction. (3) Students successfully translated between pictorial and written/metaphorical representational forms for integer addition and subtraction. Students were able to make personal connections to the metaphors based on the frequency with which students created personalized stories. And students showed evidence of making connections among the words in the story and the images in the pictures to the values of the integers used in their mathematical sentences
科技工具之特點	Virtual manipulatives shared several key features (1) dynamic linked representations (2) interactivity (3) multiple representations (4) immediate feedback) some features that were unique to each virtual manipulative (1)type of user input required (2) degree of guidance provided by the applet (3) problem presentation Virtual manipulatives had a larger impact on students' learning of integer computation than those that were unique to any one specific tool.

編號:6203

欄位名稱	內容
文獻來源	Steen, K., Brooks, D. & Lyon, T. (2006). The Impact of Virtual Manipulatives on First Grade Geometry Instruction and Learning. Journal of Computers in Mathematics and Science Teaching, 25(4), 373-391.
研究目的	Investigated the impact of virtual manipulatives on first grade students' academic achievement as well as on student attitudes, behaviors, and interactions.
研究問題	1. What differences exist among the academic achievement of first grade students who use the virtual manipulatives and those students who use the traditional text-recommended practice activities? 2. What are the treatment teacher's impressions and observations on student attitudes, behaviors, and interactions when using the virtual manipulatives?
研究方法	Thirty-one (31) first grade students were randomly assigned to either a treatment or control group. Both groups studied identical objectives, but the treatment group used virtual manipulatives for practice.
教學單元	□數與運算(Number & Operations) □代數(Algebra) ■幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	Identify spheres, cylinders, rectangular prisms, cones, and pyramids; copy a plane shape and be able to transform a shape into a larger/smaller shape; draw a plane shape with a given number of sides; draw a shape with a given number of corners; identify and draw plane shapes that are the same size and shape; state a rule for a given pattern; use problem solving strategies to continue a pattern; draw lines of symmetry; and identify and show equal parts in a plane shape.
教育階段	■國小 □國中 □高中
融入教學之工具	Virtual manipulatives that were created or reviewed by the MarcoPolo Educational Foundation (http://www.mped.org). This included virtual manipulatives from the National Council of Teachers of Mathematics Illuminations site (http://illuminations.nctm.org/), the National Library of Virtual Manipulatives (http://nlvm.usu.edu/en/nav/index.html), Arcytech (http://www.arcytech.org/), and Math Cats (http://www.mathcats.com/).
學習活動 (Learning activity)	教學策略: ＊The control group Used their student textbooks for instructional purposes, and used physical manipulatives and corresponding worksheets for practice. ＊The treatment group Used the same textbooks for instructional purposes, but used virtual manipulatives for practice. If a virtual manipulative was not available for an objective, the students in the treatment group completed the same worksheet activity as the control group. However, they never touched an actual physical manipulative throughout this study. Each treatment group student had a Macintosh@ iBook® laptop computer that was connected to the Internet by way of a wireless network. The computers were only used during the designated math time. The treatment group teacher was provided with a laptop connected to a projector for instructional use during math only.
所收集之研究資料	The tests and assessment activities
研究結果	一、量化資料 Posttest results showed that the treatment group outscored the control group on both grade level tests, though not at a significant level (p >

	0.05). The treatment group had significant improvements ($p < 0.05$) on both grade level tests, while the control group only had significant improvements ($p < 0.05$) on the second grade level of testing. 二、質性資料：學生使用虛擬教具所從事的學習活動的量、形態、以及回饋。 The virtual manipulatives kept students focused,increased the quality and quantity of practice, adapted to appropriate difficulty levels, and had other features not available when using traditional paper and pencil or actual manipulative activities.
科技工具之特點	1. Instant feedback. Students did not have to wait for Karla to check their work. With the click of a button, the computer directly and immediately indicated if they were correct. The virtual manipulative allowed a student to ask for a hint if needed. Students did not have to wait for Karla to offer advice. Features such as use of colors on the virtual geoboard and the ability to mark sides and comers on the shape spinner provided indirect feedback for the students. 2. While such features didn't provide direct feedback on the students' accuracy, they definitely made it easier for the students to self-regulate and make adjustments individually and privately. Karla also noted that these same indirect features made it easier for her to check their work by quickly glancing at the computer screens as she moved around the classroom. 3.Students did not have to clean-up rubber bands from geoboards, they did not have to put away pattern blocks, they did not have pass out manipulatives, and re-doing an activity was not an ordeal. The benefit of this time saved was the increased amount of time-on-task and increased number of repetitions of a practice activity. Karla often noted that her students were able to do more practice with the virtual manipulatives than her previous classes had done when using actual manipulatives. 4. Flexibility of the virtual manipulatives (1) Several of them were used for more than one objective. As the students became more comfortable with using the virtual manipulatives and the computers, they were able to spend less time learning simply how to use them, and could focus more on the objectives for the lesson. (2) Allowed students to go more in-depth than previous classes had done without the virtual manipulative: Students were able to see how a three-dimensional shape was comprised of several individual faces that were comprised of the sides and comers they were identifying. (3) The virtual manipulatives allowed students to adapt the activity to meet an appropriate level of challenge: While using the pattern blocks virtual manipulative, students could create patterns ranging from simple to complex. Either way, it was the students' private choice. More often than not, Karla noted that students challenged themselves to higher levels, using the features of the virtual manipulative. 5. Virtual manipulatives was that they allowed for every child to have equal access to the same high quality lessons and activities. Students did not have to wait to take turns to share actual manipulatives, which again increased time-on-task and number of repetitions. In terms of educational equity, if these virtual manipulative were used in an entire school district, it would mean that all children would have equal access to high quality and effective materials. 6. Difficulty with the motor skill of writing were able to easily use the virtual manipulatives. This allowed them to focus on the math objective instead of on the difficulty of using a pencil or stretching a rubber band across an actual geoboard. Karla reported that these two students typically struggled in math. These students excelled when using the virtual manipulatives.

編號:6208

Data Extraction Form	
欄位名稱	內容
文獻來源	Santos-Trigo, M. (2004). The Role of Dynamic Software in the Identification and Construction of Mathematical Relationships. Journal of Computers in Mathematics and Science Teaching, 23(4), 399-413.
研究目的	this study is to investigate aspects of reasoning exhibited by high school students while using dynamic software to construct and examine a set of geometric configurations.
研究問題	What features of mathematical thinking do students exhibit when they use dynamic software in their problem solving approaches？
研究方法	Eighteen high school students participated in a problem-solving course during one semester, meeting four hours a week. An important goal was to ask the participants to use Dynamic Software to work on a series of activities that involve.
教學單元	□數與運算(Number & Operations) □代數(Algebra) ■幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	Geometric configurations
教育階段	□國小 □國中 ■高中 high school students
融入教學之工具	Dynamic software
學習活動 (Learning activity)	教學策略: problem solving instruction、Participants had access to a computer but they were encouraged to work in pairs or small groups of three. We also suggested a particular pedagogic approach to encourage students to learn through an inquiry process.
	1. The instructor introduces the task to the students and asks them to work on the task in groups of two or three students for about 20 minutes. The role of the instructor is to monitor students' work and help them clarify (via questions) the statement of the task. Each small group hands in a written report showing the students' approach to the task. 2. The instructor asks some small groups to present their work to the whole class. During each small group presentation, the rest of the group, including the instructor, asks questions to clarify what may not be clear or may need some elaboration from the small groups presentation. 3. The instructor identifies strengths and limitations associated with each small group's presentation and discusses with the whole class mathematical ideas, strategies, concepts and distinct representations that are relevant to students' solutions to the task. In addition, the instructor may introduce a new concept or analyse extensions or possible connections to the original statement of the task or problem. 4. Students are asked to individually revise the initial task. Here each student has the opportunity to incorporate new ideas, concepts, or strategies that he/she has judged to be relevant during the development of the session.
所收集之研究資料	課堂觀察各小組之活動
研究結果	What features of mathematical thinking do students exhibit when they use dynamic software in their problem solving approaches? (focus on the behavior of a small group of students during the presentation of its work to the whole class.) 1. The presenter added new elements to this simple initial configuration and begin to identify and explore particular relationships among the components of the emerging construction.

	2. Students used to support this result was based on using a result that they had previously studied. 3. Students not only carefully examined the construction, but also participated in the process of justifying properties that first appeared only visually. Students eventually recognized that it was important to provide arguments to support their conjectures. 4.Students developed a certain kind of ability to add other elements to the configuration when there was a possibility of generating interesting relationships. 5.學生使用軟體時，應用兩個策略： (1)Trial and error strategy：it helps to measure particular parts of the configuration and observe whether any selected point of the hyperbola holds its definition. (2)Identify the main elements of the figure through the conic command: to associate the shown locus with the corresponding conic (selecting five points of the locus and the command conic). Here, the software can also provide the corresponding equation
科技工具之特點	1.Visually: Students have an opportunity to observe and identify properties attached to different components of the figure in order to pose and pursue particular questions. Visually identified as a particular figure actually held mathematical properties that define that figure. In particular, the use of the software seemed to help students orient the process of searching for arguments to support their conjectures. 2. Contents or theorems that students used to relate particular subjects (triangles, bisectors, with Euclidean geometry and conics with analytic geometry) together now seem to appear connected. In fact, students not only reconstruct some particular relationships but also investigate and document new ways to generate particular figures. In addition, students are able to study properties attached to those figures 3. The role of dynamic software becomes an important tool for students to guide the exploration of mathematical relationships. In some cases, the use of the software provides evidence about the existence of particular relationships. The goal here is to show a mathematical argument to justify such existences. In other cases the software itself functions as a tool to generate figures (loci) that later need to be examined in terms of their properties. Another important factor is that the use of the software allows students to quantify or measure elements involved in the figure (lengths, areas, perimeters) and document their behavior as a result of moving or changing other components within the same configuration 4.dynamic representation：Students themselves get the opportunity to reconstruct or discover new theorems or relationships. A crucial aspect that emerged in students' problem solving instruction is that with the use of dynamic software they had the opportunity to engage in a way of thinking that goes beyond reaching a particular solution or response to a particular problem.

編號:6211

Data Extraction Form	
欄位名稱	內容
文獻來源	Reimer, K. & Moyer, P.S. (2005). Third-Graders Learn About Fractions Using Virtual Manipulatives: A Classroom Study. Journal of Computers in Mathematics and Science Teaching, 24(1), 5-25.
研究目的	Examining how the use of the virtual manipulatives might enhance students' learning of fractions beyond what students had learned through the teacher's use of physical manipulatives and other instructional strategies.
研究問題	1. What impact do virtual fraction manipulatives have on students' conceptual and procedural understanding of fractions? 2. What are students' attitudes about using virtual fraction manipulatives during the learning of fractions?
研究方法	This action research project provides a glimpse into a third grade classroom showing how virtual manipulatives impacted teaching and learning in this setting. The project serves as an impetus for teachers and researchers to use virtual manipulatives in teaching mathematics in other classroom projects
教學單元	■數與運算(Number & Operations) □代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	Parts of a whole, parts of a group, comparing fractions, and equivalent fractions.
教育階層	■國小 □國中 □高中 19 third-grade students.
融入教學之工具	Virtual manipulatives (From the Grades 3-5 strand located on the National Library of Virtual Manipulatives website (http://matti.usu.edu).)
學習活動 (Learning activity)	教學策略:
	1. The physical environment of the classroom was organized for cooperative learning with desks placed in groups of five and students of different abilities at each table. teacher to focus students on features of the virtual fraction manipulatives that would be used during each lesson. 2. Students interacted with the virtual manipulatives in the computer lab on four consecutive days. Student worked independently at their own computers during the virtual manipulative activities. Interviewers were present in the computer lab during these sessions. 3. During the first week students were also introduced to the virtual manipulative applets. The teacher chose to introduce students to the virtual manipulatives by using the base-10 blocks applet. Allowing students to use this virtual manipulative prior to the study was to give students the opportunity to become familiar with computer applets. 4. During the second week of the project the teacher taught a unit on fractions in the computer lab. Each lesson began with an introduction to the virtual manipulative applet that would be used that day and several mathematical tasks for the students. On each day in the computer lab, students were given a teacher-made worksheet that provided instructions for using the virtual manipulatives and prompted them to complete several mathematical tasks. The teacher reviewed the instructions with the class and modeled how to use the virtual manipulatives before students worked independently on the activities
所收集之 研究資料	Data sources in the project included a pre and posttest of students' conceptual knowledge, a pre and posttest of students' procedural computation skills, student interviews, and a student attitudes survey.

研究結果	一、量化： 1. Statistically significant improvement in students' posttest scores on a test of conceptual knowledge, and a significant relationship between students' scores on the posttests of conceptual knowledge and procedural knowledge. 2. The majority of responses from students on their experiences with the virtual manipulatives was positive. 二、質性：Interaction Interviews(學生與虛擬教具之互動) Student interviews and attitude surveys indicated that the virtual manipulatives (1) helped students in this class learn more about four consistent themes throughout the interviews： 1. Virtual manipulatives were helping students learn about fractions. 2. Students liked the immediate feedback they received on the virtual manipulative applets. On these applets, the computer indicated when students' responses were correct or when they needed to be revised. Some applets also told students specifically which aspect needed to be changed. 3. The virtual manipulatives were easier and faster to use than paper-and-pencil. These ideas centered on the notion that the student was able to move quickly through the mathematical tasks the teacher assigned. 4. Enjoyment. This theme was indicated by comments that showed students had a positive experience while working with the virtual manipulative. Overall, these four themes were positive and indicated students felt successful during their mathematics experiences. Students indicated that the virtual manipulatives were helping them learn, they were easy to use, they gave specific feedback, and they were enjoyable to use.
科技工具之特點	1.The virtual manipulatives the students used were dynamic visual images of fraction amounts. Practicing with the visual computer images could have enhanced students' abilities to explain and represent their thinking using pictorial models. The virtual manipulatives also provided opportunities to practice using a visual model that could be changed and manipulated. Students do not have this opportunity for practice with dynamic visual representations when they view pictorial images on textbook pages or worksheets. 2. Student improvement may have been attributed to the immediate and specific feedback students received while using the virtual manipulatives. These specific instances of feedback in written form on the computer may have served the function of correcting or highlighting students' errors, making students more aware of their own misconceptions. This feedback served as a model for students that indicated how to write fraction notations accurately using numbers and words. 3. The virtual manipulatives also allowed for accommodations and differentiation of the different ability levels of the learners in this group of students. Students were able to work at their own pace; therefore, more able students completed many more tasks than students who did not work at this rapid pace. This kept the advanced students interested and engaged 4. Multiple representations on these applets also supported students with learning disabilities. The virtual manipulatives often included representations in the form of visual objects, written words, and numerical symbols. All of these representations provided support and scaffolded learning for the less able students in the group. These instances of individual feedback, multiple representations for support, and a variable pace for completing tasks may have been an important aspect in the differentiation of instruction during these lessons in the computer lab.

編號:6216

Data Extraction Form	
欄位名稱	內容
文獻來源	Iskander, W. & Curtis, S. (2005). Use of Colour and Interactive Animation in Learning 3D Vectors. Journal of Computers in Mathematics and Science Teaching, 24(2), 149-156.
研究目的	This study investigated the effects of two computer-implemented techniques (colour and interactive animation) on learning 3D vectors
研究問題	
研究方法	The students were then divided into four groups. Each group was allocated to a different version of software for learning 3D vectors.
教學單元	□數與運算(Number & Operations) □代數(Algebra) □幾何(Geometry) ■測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	3D vectors
教育階段	□國小 □國中 ■高中 High school students
融入教學之工具	Educational mathematics software: For learning 3D vectors — colour and interactive animation: Colour and interactive animation、 Non-colour and interactive animation、Colour and static images、Non-colour and static images)
學習活動 (Learning activity)	教學策略: 1. During which no lessons on 3D vectors were taught, students attended one of four separate sessions in the school's computer laboratory, according to group. Each student viewed the software at her own pace, and saw only the version of the software for her group. 2. After viewing the software, the students were given a post-test in 3D vectors, similar in structure and difficulty level to the pre-test. Students were also given a questionnaire, which was designed to explore attitudes towards the use of computers in learning mathematics, in particular the topics of graphics and colour.
所收集之研究資料	Pre-tested(questionnaire)、post-test
研究結果	All students improved their overall test scores, with no significant difference between the groups. However, test scores on the visualization questions differed noticeably, with the groups viewing animated versions scoring higher than the groups seeing static versions. 1. A significant difference in test scores from all four groups 2. No effects that resulted from either the interactivity or colour were detectable. 3. No effect resulting from colour was detectable, there was a small difference (p = 0.16) according to interactivity. 4. All students who used the interactive versions were neutral or positive about the animation and 3D figures. In contrast, 86% of the students who saw the static images thought that they would learn better from 3D representations of vectors.
科技工具之特點	1. Visualization: students viewing interactive software might be expected to produce better results(there was a small positive effect of the interactive animation) 2. Interactive: positive effect on learning 3D vectors, it would be beneficial to undertake a similar study using a greater number of students and with greater attention paid to the visualization questions.

編號:6504

Data Extraction Form	
欄位名稱	內容
文獻來源	Martin, P., & Velay, J. L. (2012). Do computers improve the drawing of a geometrical figure for 10 year-old children?. International Journal of Technology and Design Education, 22(1), 13-23..
研究目的	Would children learn to draw more easily and more efficiently if they were taught with computerized tools? To answer this question, we made an experiment designed to compare two methods for children to do the same drawing: the classical 'pen and paper' method and a CAD method.
研究問題	The present study was devoted to this question: 1. Would children learn to draw more easily and more efficiently if they were taught with computerised tools? 2. What would the advantages and disadvantages of their use be? 3. Would using a computerised graphics tool influence children's drawing skills? 4. Do these new digital tools enhance or reduce drawing abilities in terms of planning actions and conceptualising spatial relationships?
研究方法	Made an experiment designed to compare, in children, two methods for producing the same drawing: the classical 'pen and paper' method and a computerised method. Objectively quantifying the 'quality' of a drawing is a very difficult issue, even the technical quality, if the subjects of the drawings are different.
教學單元	□數與運算(Number & Operations) □代數(Algebra) ■幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	Draw a geometrical figure: the Rey- Osterrieth Complex Figure (ROCF).
教育階段	■國小 □國中 □高中 4th and 5th grade pupils in a primary school.
融入教學之工具	Computer aided design (CAD) software
學習活動 (Learning activity)	教學策略:
	We asked two groups of children to draw the ROCF. The first group drew it with a pen on a sheet of paper ('paper' group) and the second on a computer screen with design software ('computer' group). ＊Computer drawing Using a mouse the children were equipped with a pen tablet (Wacom intuos 2) and a pen. The children were seated at a table, in front of a computer screen. The model (ROCF) was presented on a piece of paper (21 9 29.5 cm) placed at the side of the computer screen. "Adobe Flash Player" was used because its graphic simplicity makes it easy for 10 year-old children to use. On the screen, a white surface, representing the sheet of paper, was shown. Both drawing surfaces, paper and digital, were of identical size. Children had to look at the model on the paper and copy it on the screen. No constraints were imposed regarding the order of the strokes. When the child drew a wrong stroke, he/she could cancel it using an eraser. We did not use the animation tools which are available in "Flash Player" but we restricted its use to the graphic tools. Children were allowed to use the ready-made shapes (square, rectangle, circle and ellipse) and the basic 'stroke' tools. For strokes and free form drawing, they could use the 'pencil' tool which is quite similar to a real pencil. They then had the possibility to straighten or to reshape the forms in order to get precise geometrical forms from the previous rough ones. For directly drawing perfect straight and curved lines or geometrical forms, they could use the 'plume' tool and the

	'ellipse' or "rectangle" tools respectively. In order to avoid favouring the 'computer' group, the practice was very short. Individual periods of 5 min were dedicated to the description by the experimenter of the various possibilities of the software. The child was asked to observe and to identify every icon associated with the drawing tools which were available. Children were tested individually. The instruction was simply to copy the figure which was on the paper. They had exactly 3 min to do it. Immediately after that, they were asked to reproduce the same figure from memory as completely as possible. ＊Paper drawing The children were seated at a table with a blank sheet of paper (21 9 29.5 cm) in front of them. The model (ROCF) was presented on a sheet of paper (21 9 29.5 cm) placed at their side. Children had to look at the model and copy it onto the blank paper. No constraints were imposed regarding the size of the figure and the order of the strokes. The children were given a ruler and an eraser and they were encouraged to use them when necessary. This procedure was different from the standard ROCF procedure in which ruler and eraser were not allowed. However, since our aim was to compare with software in which these tools were included, it was important to make them available to the 'paper' group. Immediately after the 3 min copy, the experimenter gave the children a new sheet of blank paper and asked them to draw the figure from memory as completely as possible.
所收集之 研究資料	Pre-tests、
研究結果	These preliminary results suggest that using a CAD tool could help children while they copy a model, but that it does not improve their ability to draw the same figure using their own, internal model. ＊Computer vs. paper The analysis showed that the scores were higher for children who used the computer than for those who used the paper. ＊Copy vs. memory The mean scores in the 'copy' situation were higher than those in the 'memory' situation.
科技工具之特點	1. With the available tools for line drawing or the geometrical shapes library, it is easy for children to draw straight lines and squares with exact right angles or perfectly round circles. 2. It occurred that something was not correct, the 'undo' procedure allowed instantaneous erasing without too much loss of time. 3. The children probably hesitated less when beginning their drawing because they could easily start from a given shape, and either erase it, if it was not suitable, or update it. 4. This artefactual environment helped them to anticipate and thus facilitated their work. Thanks to this device, which allowed them to reach their goal step by step, the children were able to manage their learning, even if some of the underlying concepts were only partially understood.

編號:6506

Data Extraction Form	
欄位名稱	內容
文獻來源	Hwang, W.-Y., Chen, N.-S., Dung, J.-J., & Yang, Y.-L. (2007). Multiple Representation Skills and Creativity Effects on Mathematical Problem Solving using a Multimedia Whiteboard System. Educational Technology & Society, 10 (2), 191-212.
研究目的	The aim of this study is to explore student multiple representation skills and creativity in solving mathematical problems when supported by a multimedia whiteboard system. This study explores how primary school students use multiple representations including text, graphs, symbols, rules, and formulas in mathematical problem solving; and how a multimedia whiteboard system can be used to support students in doing multiple representations. This study also wants to examine the relationship between student creativity ability and multiple representation skills and the impact on mathematical problem solving.
研究問題	1. How does student multiple representation skills affect mathematical problem solving using a multimedia whiteboard system? 2. How does student elaboration ability in creativity affects their multiple representation skills in mathematical problem solving? 3. What are the advantages and disadvantages of using a multimedia whiteboard in mathematical problem solving?
研究方法	The students were classified into different groups according to their solution representation styles. T test and One-way ANOVA were used to analyze the differences in solution, criticism and academic achievement. Pearson Correlation analysis was conducted for representation skills and creativity.
教學單元	■數與運算(Number & Operations) □代數(Algebra) ■幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	Numeric problems ：contain the concepts about arithmetic series, geometric shapes, factors, multiple items and number applications. Geometric problems： contain the concepts of volume, area of surface.
教育階段	■國小 □國中 □高中 25 six-grade primary school students
融入教學之工具	Multimedia whiteboard system: Has drawing tools, voice recording tools and editing functions. Students write down and modify their solutions and explanations on their own whiteboards, which then stores this information in the form of a discussion forum on a web site. The multimedia whiteboard system has the following functions: the drawing tools include the line, circle, rectangle and text. The editing functions including copy, paste, cut, move, undo and redo and the voice recording function.
學習活動 (Learning activity)	教學策略: Multi-modal learning simply means using many ways to learn. Multi-modal learning promotes the use of new media and methods designed and offered by communication and computer technology.
	The students participated in two math class sessions for a total of 80 minutes every week. In the experiment, students were first given two week tutorials to learn how to use the multimedia whiteboard system. After that, one week is given for solving problems followed by another week for mutual criticizing and response activities until the end of the semester. The math teacher supervised and guided the students in the class learning activities using the multimedia whiteboard system. This included solving problems, criticizing other students' solutions and responding to comments made by other peers.

所收集之 研究資料	QCAI Evaluation (QUASAR Cognitive Assessment Instrument)
研究結果	1. Representation Skills of T(Text or Voice Representation) and G(Graph or Symbol Representation) Are the Keys to Mathematical Problem Solving: Most students could easily apply formulas to get their first solution without any detailed explanation. However, many students obtained good solutions with enhanced T and G representation skills after participating in the criticism and response activities. The T and G representation skills play the most important roles in linking the learning process among 'remembering', 'understanding' and 'applying'. We conclude that T and G representation skills are the keys to successful mathematical problem solving for students. 2. Profound Effect of Elaboration Ability in Creativity on Multiple Representation Skills: The students with high elaboration ability could manipulate T and G representation skills well in problem solving. Students with high elaboration ability could take better advantages of peer interactions and teacher guidance to generate more diversified ideas and solutions in problem solving. In contrast, students with low elaboration ability had great difficulty in manipulating their representation skills well. We conclude that elaboration ability in creativity is one of the critical factors that affects student multiple T and G representation skills in mathematical problem solving. 3. Advantages and Disadvantages of Using Multimedia Whiteboard in Mathematical Problem Solving: Applying multiple representation skills to solve mathematical problems using the designed multimedia whiteboard system with mutual criticism was helpful in stimulating students with prosperous perspectives on problem solving and criticizing. Students enjoyed using the multimedia whiteboard and felt it was very interesting and useful for them to solve mathematical problems.They were highly engaged in problem solving in the computer classroom. Even in the criticism activity, they paid good attention to giving comments to others. When the students explained their solutions, criticized others' solutions and responded to others' comments using text, voice, graph, or symbol, they had the chance to reflect on whether they really understood the problem. The teachers were able to identify students that misunderstood points in each component of problem solving, and provide immediate assistance and suggestions.
科技工具之特點	When using the multimedia whiteboard system, the students can be stimulated to try their best to solve problems actively, so that several innovative and excellent solutions could be generated. Many students do not use just the known formula to solve a problem but also derive fantastic solutions using their reasoning and creative thinking. Using the Multimedia Whiteboard System to facilitate students learning mathematical problem solving can stimulate students to generate more creative solutions.

編號:6538

Data Extraction Form	
欄位名稱	內容
文獻來源	Topcu, A. (2011). Effects of using spreadsheets on secondary school students' self-efficacy for algebra. International Journal of Mathematical Education in Science and Technology, 42(5), 605-613.
研究目的	This study is an investigation of the effect of instruction that includes spreadsheet-based purposeful activities on secondary school students' self-efficacy beliefs for algebra.
研究問題	
研究方法	Experimental group (EG): 42 were placed in an which received spreadsheet-based instruction in algebra control group (CG): 40 were placed in a which received conventional instruction without spreadsheets.
教學單元	□數與運算(Number & Operations) ■代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	The topic of instruction in the CG and the EG was graphing quadratic functions and related problems.
教育階段	□國小 □國中 ■高中 82 10th grade students at a public secondary school
融入教學之工具	Spreadsheet
學習活動 (Learning activity)	教學策略:
	Students in the EG were given additional instruction on how to use a spreadsheet in mathematics, specifically how to enter data, draw a graph of a line and analyze its points on a coordinate plane. In the second hour of eight of their lessons, the students in the EG used a readymade template for a spreadsheet-based purposeful task. They worked on problems related to the purposeful task by entering data into the cells in response to facilitating questions provided by the teacher. Such a task provides opportunities to ask the sort of 'what-if' questions described by Abramovich and Roblyer, and the spreadsheet enables student to see 'what will happen if'. After these initial explorations, the teacher asked the students to develop their own spreadsheet based template for the purposeful task. In the CG, on the other hand, the teacher taught the topic in the conventional way. In the second hour of each lesson, the students worked on problems related to the purposeful task without the use of a spreadsheet.
所收集之 研究資料	Self-Efficacy for Math (SEM)
研究結果	Analysis of the data indicated that students who received spread-sheet-based instruction had significantly higher self-efficacy for algebra than those who received conventional instruction. The EG showed significantly higher ratings for SMS than the CG. For low performers and for high performers, the SMS mean difference between the two groups was not significant. On the other hand, it was significant for medium performers. In the EG, high and medium performers had significantly higher SMS than did low performers, but the SMS mean difference between high and medium performers was not significant. In the CG, the only significant SMS mean difference was between high performers and low performers. The self-efficacy scores of students in the PMP two-to-three range in the EG were significantly higher than the self-efficacy scores of students on the PMP two-to-three range in the CG.
科技工具之特點	The study found that the self-efficacy of medium performers in mathematics was most affected by the treatment. The reason for this

	finding might be that the medium performers had learned to rely on the spreadsheet as a validating tool for their solutions to problems when they had lingering questions or misunderstandings about them.

編號:6780

Data Extraction Form	
欄位名稱	內容
文獻來源	AKTAŞ, M. BULUT, M., YÜKSEL, T. (2011). The effect of using computer animations and activities about teaching patterns in primary mathematics, . The Turkish Online Journal of Educational Tehcnology, 10(3),273-277.
研究目的	In this study it is investigated that teaching of different pattern types by using computer animations and activities.
研究問題	1.Is reminding has an effect, according to presentation styles of 8th grade students, in their performances with mathematical patterns by using computers? 2. Is there a significant relationship between performances regarding mathematical patterns according to presentation styles of patterns at the reminding in 8th grade students by using computer?
研究方法	The one group pre-test post-test design was used for research methodology.
教學單元	■數與運算(Number & Operations) □代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	Linear pattern
教育階段	□國小 ■國中 □高中 28 eighth grade students
融入教學之工具	Microsoft PowerPoint
學習活動 (Learning activity)	教學策略: The application was carried out for four hours with 28 students in the 8th grade in a primary school chosen for the application. In the first lesson pretest was applied. Students knew pattern presentation styles which could be shown in three different ways comprising shape, number sequence and table. During the application students were educated for two hours by using computer in a way to remind presentation shapes. The presentations which were used during the application were prepared by the scientists in accordance with the curriculum by scanning necessary literature. Different examples belonging to three different presentation styles were solved with the students and the application was completed and following this a post test was applied.
所收集之研究資料	Data were collected by pre-test and post-tests which were developed by researchers and it was revised in terms of reliability and administered to the students. The subject was showed by using computer to the students after pre-test. At the end of the teaching, that achievement test was applied on the group as the post-test.
研究結果	Quantitative methods were used. According to the findings; academic performance of the students increased by using computer animations and activities about patterns. Also, it is found that there was a significant difference between academic performances of students about different pattern types. 1. This finding shows that the reminder, made by computer, has a significant effect on increasing the academic achievement of the 8th grade students in linear increased pattern. 2. The finding shows that the students are more successful with the figure presentation and number sequence presentation style than that of form presentation style.
科技工具之特點	Enabling active participation and addressing more than one feeling at the same time, computer makes the learning states more dynamic and

	colourful. Because of all these reasons, it is thought that computer aided teaching can be used effectively with many lessons including even mathematics.

編號:灰一

Data Extraction Form	
欄位名稱	內容
文獻來源	P. A. Forster. (2006). Assessing technology-based approaches for teaching and learning mathematics. International Journal of Mathematical Education in Science and Technology, 37(2), 145–164.
研究目的	The research purpose was to investigate the use of technology for teaching and learning statistics
研究問題	The unit of analysis in the account below is the class: opportunities for learning are described, but understanding is not claimed for all students. The extent to which activities resulted in successful learning is indicated by assessment test evidence.
研究方法	The setting was an all-girls' private school in Western Australia. The Year 12 class was studying Applicable Mathematics [42], a tertiary entrance examination (TEE) subject for which graphics calculators are mandated. There are three TEE mathematics subjects: Calculus, Applicable Mathematics and Discrete Mathematics. Applicable Mathematics is the second in mathematical demand after Calculus. Some students study both Applicable Mathematics and Calculus. Seventeen consecutive lessons were observed during the teaching of descriptive statistics. Measures of central tendency, dispersion and correlation, the effects on them of changes in origin and scale, least squares regression, and analysis of residuals were addressed. Boxplots, and graph for the least squares regression line, and residual plots were introduced.
教學單元	□數與運算(Number & Operations) ■代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	Calculus, Applicable Mathematics and Discrete Mathematics.
教育階段	□國小 □國中 ■高中 Year 12 class
融入教學之工具	Graphics calculators、 Java applets
學習活動 (Learning activity)	教學策略： Students used their graphics calculators in solving textbook questions but the collected data does not support an analysis of mathematical understanding developed through that work. 1. Least squares regression: the activity The class was working with a set of (height, thickness) data relating to scallop shells. The teacher-led discussion on covariance and correlation for the data. Students calculated the measures by hand and accessed the values on their calculators. Then, the teacher led the class in producing a scatter plot on their calculators (see figure 1) and posed the question of how to predict the thickness of a scallop shell given its height. The class had drawn scatter plots on graph paper and fitted lines to data by eye in lower-secondary school, and had used the lines for prediction, but they had not calculated and predicted off the regression equation. Before any discussion on the prediction, the teacher moved to project the display from his laptop onto the whiteboard. He accessed a Java applet off the web. Statistics, including the correlation coefficient, mean values, and the equation for the regression line, were displayed below the graph. The teacher added points to the graph by clicking in the graph space. The regression line and statistics were automatically updated. Class discussion on the graph resulted in the least squares regression relationship being partially defined. A more complete definition was obtained through discussion that centred on two other graphs. The

	teacher drew one of these on the whiteboard was on a second Java applet off the web. This applet allowed the teacher to add points, drag points, and drag the line so that the area of the squares on the residuals was minimized. A numerical expression below the graph showed the sum of the squares.Students moved from mentioning elements on the graph to specifying the calculation in terms of distances, which were not represented in any lasting, material way on the graph. Thus, they moved to abstract thinking in terms of distance. The definition of a method for calculating the line became more precise through the visual stimulus, and through the teacher asking questions and seeking explanation. Then the teacher asked which distances to use and no-one offered an answer. A typical intuitive interpretation is that the distances are diagonal. The teacher's response was to sketch a graph on the whiteboard and draw in the conventional distances—in the y direction. Students responded appropriately to the teacher's questions, and the description of how to calculate the line was advanced. Students suggested using absolute values of distances, then squares of the distances, and to sum these. The teacher dragged points on the graph and dragged the line to change its gradient and y intercept, and asked how to calculate the best line for a given set of data. Students said to 'lessen' and 'minimize' the sum and, when asked, gave suggestions on how to achieve this (increase/decrease the gradient and/or the y intercept of the line). Thus, they articulated what was involved in minimising the squares. The teacher finished by naming the method as the least squares regression method. After the demonstration, the teacher directed students on the procedures for producing the regression line on their calculators for the scallop shell data. 2. Least squares regression: an overview. From an analytical viewpoint, the students could see the applet graphs being transformed (points were added and graphical effects on the mean point, line, and squares on the residuals were visible); and they could see changes in the graph translated to numerical and algebraic forms. Seeing the transformations and end products of translation allowed but did not guarantee discernment of their basis (the regression principle). With the first graph, students focussed initially on the mean point, the data and the line, which were all visible. Distance was not represented and was mentioned only after questioning by the teacher. As noted by others the visible elements on the display, and the nature of the icons used, the intervention by the teacher, influence strongly what students notice and infer. Using the three graphs and asking students to make the connection with the concept of standard deviation allowed progression from known concepts to a new concept and from imprecise to precise definitions of regression, and therefore could be seen to be consistent with a constructivist view of learning, where students construct their own understandings step-by-step. 3. Other knowledge construction activities. Other than for linear regression, the teacher used class discussion, diagrams on the whiteboard, and gesture when introducing new statistics constructs, for example, measures of dispersion and correlation, change of origin and scale relationships, box plots and residual plots. Calculation and graphing activities, including on the calculator, followed the initial introductions. The purposes for the calculator activities were consolidating and expanding initial understandings. As well, they addressed misunderstandings that were voiced by students. With box plots, the teacher asked the class to plot test results for two groups of students, and to explain the shape of the plots. The plots had missing whiskers. The problem had arisen that students were overinterpreting the information that is available on box plots. The extraordinary missing whiskers seemed to motivate correct interpretation: students seemed to

	realize that little can be said about the number of data points and the distribution of data from inspection of a plot. Checking the box plot output against the tabulated data seemed to assist understanding. 4. Discussion The box plot and summary statistics activities required students to reconstruct processes performed by the calculator. Students discussed their work, and as well there was whole-class discussion. One student's calculator was connected to the view screen throughout the activities and this arrangement seemed to provoke discussion. Students checked outputs on their own calculators against the projected display, asked questions about discrepancies, and whole-class discussion was centred on the display. Reconstructing the box plots involved checking the extreme values, and median and quartile values on the plots against (a) extreme values in the numerical data and (b) quartile and median values which students calculated for the data. The students had practised the calculations previously and reconstruction was relatively simple. They seemed to cope well with the activity.
所收集之 研究資料	Data included: field notes made in class; video-recordings of lesions, with the view-screen and data-projector displays in the field of view; photocopies of assessment tasks and students' assessment scripts; as well as notes made during informal interviews with students as they worked, and notes made during interviews with the teacher after lessons and in relation to initial analyses.
研究結果	All students judged correctly that randomness in the residuals indicated that a regression model was valid. The properties discussed in relation to the missing whisker box plot and the ability to detect outliers were not tested.
科技工具之特點	1.Direct manipulation of the graphs was possible, so students could see the graphs being transformed dynamically. 2. The graphs were linked to other representations and the linked representations could be viewed simultaneously, which facilitated comparison of changes in them. 3. The graphs included visual clues (the mean point and squares on the residuals) which pointed to the inference that was intended.

編號:灰二

Data Extraction Form	
欄位名稱	內容
文獻來源	Tajudin, M., Ahmad Tarmizi, R., Wan Ali, W. Z., & Konting, M. M. (2007). The Effects of Using Graphic Calculators in Teaching and Learning of Mathematics. Malaysian Journal of Mathematical Sciences, 1(1), 45-61.
研究目的	The main purpose of this study is to investigate the effectiveness of using graphic calculators (TI-83 Plus) in teaching and learning of mathematics on Form four secondary school students' mathematics achievement and their metacognitive awareness in the learning area of Relation and Function. Students' views about their experiences, benefits and difficulties in using graphic calculators in learning of mathematics were sought. Specifically, the objectives of this study were: 1. To compare the effect on students' mathematics achievement during the study of straight lines using graphic calculators and the conventional methods. 2. To compare the effect on students' metacognitive awareness during problem solving of straight line problems between the graphic calculator group and the conventional group. 3. To describe students' views from the graphic calculator group on: (1) Their experiences using graphic calculators during the study of the straight line. (2)The benefits of using graphic calculators during the study of the straight line. (3) The difficulties experienced during the use of graphic calculators during the study of the straight line.
研究問題	
研究方法	Design of the study. This study employed the quasi-experimental, non-equivalent control posttest design.
教學單元	□數與運算(Number & Operations) ■代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	straight lines
教育階段	□國小 ■國中 □高中 The sample for this study consisted of two classes of Form four students from one of the secondary schools.
融入教學之工具	Graphic calculators (TI-83 Plus)
學習活動 (Learning activity)	教學策略： The instructional materials for this experiment consisted of six sets of lesson plans of teaching and learning about Straight Lines. The format of each lesson plan includes activities for the following phases: set induction, acquisition, practice, closure and evaluation phases. In the acquisition phase, the experimental group was first introduced to the concept of each subtopic of the straight lines using the TI-83 Plus graphing calculator. The main features of this phase were that they highlighted exploratory and discovery learning of the topic. This was followed by the practice phase: first, they were required to solve the given problems using a graphic calculator, and second, they were not allowed to solve the given problems using the graphic calculator. The practice phase was followed by the closure phase where the important concepts learnt were highlighted. At the end of the lesson, each student was given an evaluation. Two questions were posed. For the first question, the students were asked to solve the problem using a graphic calculator, and for the second question, they were to solve the problem

	without using the graphic calculator. The control group was also guided by the same instructional format with one exception. The conventional mathematics instruction method did not incorporate the use of TI-83 Plus graphic calculator. It was a whole-class instruction with the following activities: ・ Teacher explains the mathematical concepts using only the blackboard. ・ Teacher explains how to solve mathematical problems related to the concepts explained. ・ Students are given mathematical problem solving to solve them individually. ・ Teacher handles discussion of problems solving. ・ Teacher gives the conclusion of the lesson.
所收集之 研究資料	Straight Lines Achievement Test (SLAT), a Metacognitive Awareness Survey (MCAS), and a Graphic Calculator Usage Survey (GCUS).
研究結果	1. Student's Achievement The use of graphic calculators can enhance learning performance among students. 2. Student's Metacognitive Awareness Level There was insufficient evidence to conclude that the use of graphic calculators in teaching and learning mathematics can boost students' metacognitive awareness level during mathematical problem solving. 3. Majority of the students responded positively and favorably towards using graphic calculators in teaching and learning about Straight Lines.
科技工具之特點	1. The use of graphic calculators helped them to understand the straight lines concept better. They claimed that graphic calculators enhanced student performance, helps in determining the value of gradient easier, draws graphs easier, helps in solving problems, and provides information and various graphing capabilities. 2. The use of graphic calculators helped them to get accurate answers faster. In addition, they can save time and papers when doing problem solving.

編號:灰三

Data Extraction Form	
欄位名稱	內容
文獻來源	S.C. Kong, L.F. Kwok. (2005). A cognitive tool for teaching the addition/subtraction of common fractions: A model of affordances. Computers & Education, 45(2), 245-265.
研究目的	The aim of this research is to devise a cognitive tool for meeting the diverse needs of learners for comprehending new procedural knowledge. A model of affordances on teaching fraction equivalence for developing procedural knowledge for adding/subtracting fractions with unlike denominators was derived from the results of a case study of an initial prototype of a graphical partitioning model. In order to study the capability of the model of affordances for teaching knowledge of fraction equivalence and to investigate the relationship of these capabilities with the ability of learners to generate procedural knowledge for adding/subtracting fractions with unlike denominators, the CT needs to be evaluated. The purpose of this study is to establish a model of affordances on teaching fraction equivalence for developing procedural knowledge on adding/subtracting fractions with unlike denominators.
研究問題	1. What are the learning outcomes of learners after working with the CT? 2. What is the relationship between the knowledge of fraction equivalence and the capability of learners to generate procedural knowledge for adding/subtracting fractions with unlike denominators by using this CT? 3. Do different groups with different mathematics ability differ in their learning outcomes? Do different groups with different mathematics ability differ in their modes of interaction with the model of affordances? Is there any evidence on tool-affordances?
研究方法	This study uses a quasi-experimental design to study knowledge generalized by learners after working with the CT. The pre-test–post-test control group design is adopted to study the performance of the experimental group. For both the experimental and control groups a quantitative pre-test and a post-test were administered to measure the learners knowledge of fraction equivalence and their procedural knowledge for adding/subtracting fractions, before and after the experiment, respectively. One class of 12 students in the experimental group used the CT for learning fraction addition and subtraction. Another class of 12 students in the control group received no treatments. There were a total of 48 subjects with 24 in the experimental group and 24 in the control group. All the learning and teaching activities were video-recorded and tracked. The major interactions of the learners with the features of the CT, such as dragging a fraction bar for comparing fraction equivalence, were tracked by the CT and recorded on a database server. Learners were also interviewed on their views of the helpfulness of the support offered by the CT. The following section reports on the experimental data.
教學單元	■數與運算(Number & Operations) □代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	分數加減法(adding/subtracting fractions)
教育階段	■國小 □國中 □高中 the fourth grades
融入教學之工具	cognitive tool: Graphical Partitioning Model
學習活動 (Learning	教學策略：

activity)	Each learner worked with an assigned computer in the learning sessions. The researcher and assistants coordinated the learning and teaching activities, which included learning and engaging with the CT, completing worksheets, explanations, instructions, discussions and assessment. 1. Represent fractions in geometrical forms as part of a partitioned whole and vice versa. Learners have to observe: (a)inverse relationship between number and size of subparts of a unit, and (b) same unit size for the comparison of fractions. CT for associating fraction symbols with graphical representations 2. Add/subtract fractions with like denominators and attempt to relate the operations to the concept of measurement. CT for developing concept and procedural knowledge on adding/ subtracting fractions with emphasis on adding/subtracting unit fractions. 3. Develop knowledge of fraction equivalence by formulating the concept of fraction equivalence in an area model and associating it with computational skill. CT for developing concept of fraction equivalence. 4. Develop knowledge of equivalence between mixed fractions and improper fractions. CT for realizing equivalence of mixed and improper fractions in graphical form by partitioning an integral unit into a fractional whole. 5. Add/subtract fractions with unlike denominators and introduce the ‘‘borrowing’’ concept for subtraction when insufficient fractional parts in the subtrahend. CT for developing concept and procedural knowledge on adding/ subtracting fractions with emphasis on finding common fractional parts and sufficient subparts for subtraction by partitioning
所收集之 研究資料	Pre-test and post-test.
研究結果	Results of the study indicated that the model afforded learners, with various abilities for learning, knowledge of fraction equivalence. The key for mediating the generation of procedural knowledge for adding/subtracting fractions with unlike denominators in working with our cognitive tool was the concept of fraction equivalence and the capability of computing this. 1. The experimental group performed significantly better than the control group after controlling for the pre-test scores in both the learning outcomes – on developing the concept of fraction equivalence, and in gaining procedural knowledge on adding/subtracting fractions. (1) The model of affordances enabled learners to develop the concept of fraction equivalence. (2) With the mediation of the CT, learners were able to generate procedural knowledge on adding/subtracting fractions with unlike denominators. 2. Knowledge of fraction equivalence and procedural knowledge generation. Procedural knowledge on adding/subtracting fractions with unlike denominators would be likely generated by learners working with our CT if knowledge of fraction equivalence were developed from a conceptual understanding of its meaning. 3. Group differences on learning outcomes and tool-affordances (1)The CT enabled learners with high and medium mathematics abilities to generate a strong concept of fraction equivalence and procedural knowledge on adding/subtracting fractions with unlike denominators. (2) However, the CT enabled only a handful of learners with low mathematics ability to generate the procedural knowledge because the CT could not help them in general to generate the concept of fraction equivalence. 4. There was no evidence in this study of differences in the different mathematics ability groups in the learners modes of interaction with the model of affordances for learning fraction equivalence.

科技工具之特點	There was evidence of tool-affordances. The feature of dragging the fraction bar for comparing equivalence was well perceived by learners. The popularity of this selection reflected the tool affordances design of this feature. There was also evidence of the tool-affordances of the feature for the further partitioning of a fraction bar into equivalent forms, as they were used according to design. However, the feature on dragging the hypothesized fraction bar for comparing equivalence needed further study to investigate its affordances.

編號:灰四

Data Extraction Form	
欄位名稱	內容
文獻來源	Healy, L., & Hoyles, C. (2001). Software tools for geometrical problem solving: potentials and pitfalls. International Journal of Computers for Mathematical Learning, 6(3), 235–256.
研究目的	We explore the role of software tools in geometry problem solving and how these tools, in interaction with activities that embed the goals of teachers and students, mediate the problem solving process. Our aim in this paper is to examine in detail how student strategies for constructing, conjecturing about and proving geometrical relationships are mediated by Cabri tools.
研究問題	1. Will students' use of Cabri tools help them to make transitions to and from theoretical constructs and their empirical manifestations? 2. Will students simply bypass mathematics and come to rely solely on empirical feedback to make judgements and solve problems? 3. Will the use of tools lead students down into mathematical cul-de-sacs from which they can neither progress nor backtrack?
研究方法	Our goal was therefore to design construction activities in which students had to attend to and make explicit the relationships they used in their constructions – the 'given' properties and relationships – and distinguish these from properties that could be deduced as necessary, after observing their invariance on dragging in Cabri. To achieve this goal, we organised the computer activities into a teaching sequence comprising four phases. In the first phase, students were required to construct a geometrical figure with Cabri, identify and describe the properties and relations they had used in their constructions, use the computer tools to generate and test conjectures about further properties that might also be true, and finally make informal explanations of why they might be true. During this phase of work, the role of the teacher was to facilitate and prompt rather than to instruct. In the second phase, the teacher played a more directive role, bringing the students together to introduce them to writing proofs. Students were helped to organise the explanations they had generated during the computer activity into logical deductive chains. The third phase was essentially a repetition of the first phase with the added requirement to write a proof of one conjecture. In the final phase (the core of this paper), the students were given a challenging problem, in which they were asked to construct a figure with Cabri using any of the tools with which they had become familiar, and identify, explain and prove any of its properties.
教學單元	☐數與運算(Number & Operations) ☐代數(Algebra) ■幾何(Geometry) ☐測量(Measurement) ☐資料分析與機率(Data Analysis & Probability)
教學主題	geometrical problem solving
教育階段	☐國小 ■國中 ☐高中 14 and 15 years
融入教學之工具	Dynamic geometry software
學習活動 (Learning activity)	教學策略：
	In the first phase, students were required to construct a geometrical figure with Cabri, identify and describe the properties and relations they had used in their constructions, use the computer tools to generate and test conjectures about further properties that might also be true, and finally make informal explanations of why they might be true. During this phase of work, the role of the teacher was to facilitate and prompt rather than to instruct. In the second phase, the teacher played a more directive role,

bringing the students together to introduce them to writing proofs. Students were helped to organise the explanations they had generated during the computer activity into logical deductive chains. The third phase was essentially a repetition of the first phase with the added requirement to write a proof of one conjecture. In the final phase, the students were given a challenging problem, in which they were asked to construct a figure with Cabri using any of the tools with which they had become familiar, and identify, explain and prove any of its properties.

＊In the first phase of the teaching sequence, we introduced the students to a set of tasks involving congruent triangles. Our aim was that students would discover the conditions for congruency by finding out whether or not pairs of triangles, one given and one constructed according to certain conditions (for example with equal sides, or with two equal angles and one pair of equal sides), remained exactly the same, or congruent, under dragging. The students opened a file containing a general Cabri triangle, ABC. They were then asked to find minimum sets of properties required to construct a triangle congruent to ABC. To help them specify the properties, we added two construction tools, or macros, to the Cabri construction menu. The first macro, compass, allowed a user to construct line segments equal in length to a given segment; the second, angle-carry, enabled them to do the same for angles. Hence triangle DEF in Figure 1 was constructed by using the compass tool to copy the lengths AC and CB and the angle-carry tool to copy the angle $A\hat{C}B$. Students could verify whether or not the second triangle, DEF, was always the same as the first under dragging and so could convince themselves that the two triangles were congruent or not. In addition to the dragging test, students could make use of various other tools during their verification activities: they could ask for measures of any segments and angles to check invariant relationships, or they could use the Cabri tool, check-property. We encouraged students to use this latter tool, as it required them to declare explicitly their conjectured relationships between objects and to test whether visually-apparent properties (such as equality) were true in general. Additionally, we thought that by providing a counter-example to illustrate when conjectures were not true, the use of this tool would assist in the students in 'seeing' important relationships The check-property tool is one of the tools that has changed with the advent of Cabri II; the counter-example feature has gone and properties are declared true only on the basis of specific cases. As well as verifying their constructions, we required students to identify explicitly the properties they had used to build their second triangle, and so wished to take advantage of the tools Cabri provided to facilitate communication. We conjectured on the basis of our Logo experience, that tools that described the construction process in linguistic terms would take on special significance when construction was achieved by a set of physical manipulations. Two tools were available in Cabri I, but not in Cabri II. First, a user could replay the entire construction process using the history tool, which included a step-by-step description of the macros used. For the congruent triangles tasks, this level of detail of steps in the macros turned out to obscure the pertinent triangle properties. Second, with the exposition tool, the user could display a symbolic description of the menu selections and mouse clicks used. Since this output closely matched what we required, we encouraged the students to use it as a means to help them to reflect on their constructions and decide on the properties necessary and sufficient for congruency.

＊In the second phase of the teaching sequence, the teacher (one of the authors) introduced the students to writing formal proofs. The students were brought together in a group away from the computers, and asked to share their explanations of what had happened on the computer. They

	were then shown how to organise these explanations into logical deductive chains of argument. The students then experimented with more Cabri construction tools, including parallel and perpendicular lines and angle bisectors, before working on the next set of constructing and conjecturing activities in phase three. These activities involved the construction, exploration and deduction of properties of familiar quadrilaterals (for example, parallelograms, rectangles, squares and rhombi). The students were asked to construct each quadrilateral and identify the properties that they had chosen to use in order to define it (what we called, the givens). Next, the students explored their Cabri quadrilateral by dragging, in order to isolate further properties that always appeared to hold true. Theo, for example, noted that the opposite sides of his rectangle were always of equal length. Finally, the students had to select one of the deduced properties (DPs) from their list, and write a proof to show how it could be deduced from the properties they had declared as their givens. After the first three phases of work, the students were comfortable using Cabri and were becoming accustomed to the requirements of the activities; that is to experiment, conjecture, explain and finally transform explanations into logical deductions. They then moved to the final problem solving phase, where we hoped they would bring together all their knowledge of the tools of Cabri to solve a new challenge. ＊In the final activity in the teaching sequence, the angle bisectors construction, the students were again asked to construct a quadrilateral, but this time, the quadrilateral was one with which they were not familiar. Students were given a property of this unknown quadrilateral, namely that the angle bisectors of two adjacent angles crossed at right angles, and asked to construct it. Their challenge was to discover other properties that also had to be true if the quadrilateral was to satisfy its initial conditions, by experimentation with any Cabri tools they wished, and then to put together a logical argument starting with the initial conditions and deducing these new properties.
所收集之 研究資料	We present some of the students' strategies in response to this task to illustrate how interactions with the Cabri tools on some occasions facilitated transitions to and from conjectures to proofs.
研究結果	Successful Student Responses: Smooth Transitions between Creation, Construction, Conjecture and Deduction. Interacting with Cabri can help learners to explore, conjecture, construct and explain geometrical relationships, and can even provide them with a basis from which to build deductive proofs. Less Successful Student Responses: Constructing the Givens and Reaching an Impasse.
科技工具之特點	Tools to Assist in 'Seeing' the Necessary Relationship：Students that they use Cabri tools to keep track of the locations of the vertices A and D that produced the required perpendicularity in the figure, to help them notice the required relationship. Students combined geometrically-based constructions with visual methods to come up with conjectures, to 'see' how they might be explained, and finally, with the help of measuring tools, begin to formulate a proof.

編號:灰五

Data Extraction Form	
欄位名稱	內容
文獻來源	Tabach, M., Hershkowitz, R., & Arcavi, A. (2008). Learning beginning algebra with spreadsheets in a computer intensive environment. The Journal of Mathematical Behavior, 27(1), 48-63.
研究目的	We focus on the ways students (from two different seventh grade classes throughout 2 consecutive school years) worked on a problem situation within the CIE. The work of the students in this problem situation serves as a window to examine, characterize and analyze (both quantitatively and qualitatively), the kinds of mathematical activity which took place in this CIE for beginning algebra. One of the goals of this study is to illustrate and discuss the function of a CIE in a beginning algebra classroom with learning materials designed ad hoc—where the computerized tools (mainly spreadsheets) are available to the students at all times.
研究問題	
研究方法	The study reported in this paper is part of a longitudinal research on students' learning processes of beginning algebra in a CIE, and it focuses on the description and analysis of: (a) an example (one problem situation) of how seventh graders function in a CIE, (b) issues of beginning algebra with a functional approach using spreadsheets, and (c) the processes of instrumental genesis thereof. This paper focuses on the qualitative and quantitative analyses of students' work on one problem, which serves as a window through which we learn about the ways students worked on problems throughout the year. The analyses reveal the nature of students' mathematical activity, and how such activity is related to both the instrumental views of the computerized tools that students develop and their freedom to use them. We describe and analyze the variety of approaches to symbolic generalizations, syntactic rules and equation solving and the many solution strategies pursued successfully by the students. On that basis, we discuss the strengths of the learning environment and the open questions and dilemmas it poses.
教學單元	□數與運算(Number & Operations) ■代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	代數方程式表示式(algebraic expressions)
教育階段	□國小 ■國中 □高中 Seventh grade
融入教學之工具	Spreadsheets
學習活動 (Learning activity)	教學策略：
	1. Initiation. The teacher read a loud a problem situation from the textbook, made clarification remarks as needed, and checked for students' understanding of the task. This part took approximately 5 min, and then the students proceeded to work. 2. Students at work. Students worked either in pairs or alone, as the teacher circulated among them, asking about their approaches, processes and thinking strategies and answered technical questions regarding use of the computer. When a pair of students had a question and the teacher was not available, they turned to their neighbors for help. Occasionally the teacher initiated clarifying dialogues with pairs that she knew might need special help. 3. Summary. About 20 min before the end of lesson, the teacher asked the students who worked on the computer to save their work, and proceeded to conduct a whole class discussion. During the class discussion, the

	teacher invited students to share their working strategies, and requested the students comment and present alternative approaches (which she saw developing). Strategies were examined for correctness, efficiency and originality. The collective discussion of both fruitful and unfruitful (or incorrect) solution paths were intended to encourage and support reflection, awareness of advantages and pit falls of various strategies, mutual respect and the development of productive socio-mathematical norms. When needed, the teacher introduced relevant formal terms or concepts that she considered relevant for the summary. 4. Homework assignment. After each lesson, homework was assigned based on classroom related work. Some of which students submitted via electronic files or by e-mail. The possibility of using the computer at all times for different purposes was introduced to students from the very beginning of the school year. Functions of spreadsheets were introduced during the second lesson of the course with a guided task (many students were acquainted with the tool from previous years). Graphical representations and the way the spreadsheet processes them was introduced during the third lesson. Savings is a concatenated sequence of three tasks (each of them intended for a 90min session), in which students have to explore the growth of different kinds of savings during each of 52 weeks. In the process, students learn (in context) the roles and meanings of constants and variables, by using verbal, numerical, graphical and symbolic representations and by comparing different kinds of growth phenomena. These tasks exemplify the design and implementation of the function approach to algebra in which growth and change can be expressed by symbolic or “semi-symbolic” rules with or without spreadsheets, and supported by verbal and graphical representations. When Savings was administered (in the fourth week of classes and over a period of 2 weeks), students had had a gradual acquaintance and some experience with different representations, and with the use of spreadsheets. The first task presents four linear ways of saving pocket money on a weekly basis. Each way is presented in a different representation, and students are asked to compare the four ways. Students may choose their “favorite” representation and translate to it the four ways in order to enable an easy comparison. The second task describes in words a fifth way of saving money, starting with an initial small amount which grows exponentially. Representing exponential change with an explicit symbolic model is beyond the algebra knowledge of beginners. However, the availability of a tool like spreadsheets enables students to focus on the recursive relationship (between two consecutive elements), and use the “dragging” capability to get a numerical and a graphical representation of the phenomenon over a certain period of time. Exponential change is surprisingly different from linear change for most students. They are asked to hypothesize and then to investigate (using spreadsheets) the question of whether (and if so, by how much?) an amount of money (saved according to the given exponential rule) reaches or exceeds the amounts saved and explored in the first task. The third task starts by focusing on symbolic manipulations of linear expressions. When this task was administered (during the fifth week of the course), the students had not yet learned how to add two symbolic expressions of the form $ax + b$. Hence, their work was intended to be driven by the meanings of these expressions within the situation, rather than by following syntactic rules. At this stage of their learning, the students were able to perceive the expressions mostly as a compact way of stating a verbal sentence, i.e. the expression $30 + 12x$ stands for the savings at a certain point in time (week x), namely as the sum of the initial 30 NIS[3] and the 12 NIS which are added weekly.

	The second part of this task brings implicitly to the fore the concept of equation. Students are required to distinguish between increasing and decreasing savings based on their symbolic representations, in order to find which combination will first reach a needed amount. For that purpose, their attention should be turned to both the initial condition (i.e. the starting amount expressed by the constant in the formula y = ax + b) and the rate of change (expressed by the coefficient of the variable). There are no instructions or suggestions for using the computer to work on this task; students are allowed to follow their own initiative, based on their previous class experiences, preferences and expectations. From this point onward, we will focus on the third task, qualitative and quantitative data analyses of the students' work and we will refer to it as "the task"
所收集之 研究資料	Working files of all 21 teams、Audio-recordings from the work of 10 teams (5 from each cohort, randomly selected)、A video-recording of one team of the first cohort (due to practical constrains video could not be used further)、The teacher's diary with entries before, and immediately after each lesson (describing the learning goals, plans, expectations, including the lesson description, informal perceptions, surprises and post-hoc reflection)、Field notes taken by another researcher during the first year. (In the second year only the first author was present in the classroom.)
研究結果	＊Analysis of the five pairs of students' work on both parts of the task: 1. The diversity of approaches and the different instrumental views chosen by different teams working on the same task and with the same tool is noticeable. As expected by the researchers' intentions behind the design of these tasks, students resorted to the contextual meaning of the problem situation to advance their knowledge (of algebra). Also, the availability of appropriate working tools allowed students the autonomy to decide when to use the tool and, on the basis of such a decision, also to choose the kind of symbolic generalization. These findings seem to show that, in a class with these characteristics, students can be introduced to algebra respecting their idiosyncratic ways of sense making: arithmetical (adding columns), recursive (local generalization), and explicit (global). These idiosyncratic ways are supported by tools which can become flexible instruments for bridging between numbers and symbols. 2. Students used the tool after they identified a need, and envisioned that some functions of the tool may be useful (or "convenient") to meet it. This is related to their instrumentation processes, of which we saw a variety of examples. 3. In spite of the diversity of the ways in which students solved the problem situation, all of them seem to have grasped the idea of phenomena of growth and change. 4. Students' translations between the verbal and the symbolic representations were central to their progress. The situation itself (Savings) became a leading representation which served as the meaningful anchor against which students checked their progress with the symbolic representations, and thus led the choices of when, and how to use the tool and even to suggest new questions to explore. 5. One of the instrumental uses of spreadsheets was to contrast results against expectations (like Gal and Oryan, or Yishay and Nissim). This meta-cognitive function was for many students a central feature of their instrumental genesis, fueled by their strong desire to keep close to the meaning of the problem situation. ＊Quantitative analysis 1. There are field-notes from one pair of students showing that they explicitly expressed their willingness to "see graphically the savings of each child". These students first created a numerical representation of the savings over time using a recursive symbolic strategy, and then

	proceeded to create the graph. This piece of data is not only another confirmation of the variety of approaches, but it is also an indication that students exerted their autonomy and felt it was legitimate to proceed on the basis of their curiosity using specific (graphical) features of the computerized tools. 2. We found three interesting strategies for the instrumental generation of a tabular representation. One team of students expressed the individual savings with explicit expressions, but used a recursive expression for each of the combined amounts, showing a mixed perception of the instrument as supporting both recursive and explicit expressions. Three teams used explicit expressions to represent the individual savings, and did not use spreadsheets to represent the combined amounts. Two other teams represented explicitly the individual saving growths in spreadsheets, and then chose to add these columns cell by cell (bypassing the use of algebraic symbolism) to obtain the combined amount over time (e.g. Danielle and Amelia, see Fig. 6 above).
科技工具之特點	The environment, by including a powerful tool like the spreadsheets, also allowed students to lean back on numerical strategies when they felt the need to do so. Thus students were able to produce numerical and symbolic strategies for a same problem and to back them by verbal contextual explanations which enriched the solution approaches and at the same time allowed to smooth the usually abrupt transition from arithmetic to algebra. In the process, students adopted and adapted the tools to their needs.

編號:灰六

Data Extraction Form	
欄位名稱	內容
文獻來源	Ke, F., Grabowski, B. (2007) .Game playing for mathematics learning: cooperative or not? British Journal of Educational Technology, 38(2), 249-259.
研究目的	The purpose of this research was to explore whether computer games and cooperative learning could be used together to enrich K-12 mathematics education.
研究問題	1. TGT cooperative gameplaying would result in significantly greater maths performance and maths attitudes than with competitive gameplaying, and both would perform significantly better than the no-gaming group. 2. Gameplaying would result in significantly greater performance and more positive maths attitudes for boys than for girls, and for economically disadvantaged students than economically normal students in the control group.
研究方法	Employing a pretest–posttest experimental design, the study examined the effects of cooperative gameplaying on fifth-grade students' maths performance and maths attitudes when compared to the interpersonal competitive gameplaying and control groups.
教學單元	■數與運算(Number & Operations) ■代數(Algebra) □幾何(Geometry) ■測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	These games contained a variety of problems, including measurement, comparing whole numbers, solving simple equations and mapping x and y coordinates.
教育階段	■國小□國中 □高中 six fifth-grade
融入教學之工具	ASTRA EAGLE: a series of web-based computer games.
學習活動 (Learning activity)	教學策略：individual、cooperative、cooperative learning.
	Participants of the two gameplaying groups took two orientation sessions, during which they read the guidelines and tried each web-based game. They were then required to play one maths game during two 40-minute sessions each week for 4 weeks. Participants were seated in their own classrooms, each with an Internet connected laptop. The teachers administered the treatments, setting up in-class gameplaying sessions and monitoring the participants' activities. The teachers also had a 1-hour training session and were given administration job-aids. The researchers observed most gameplaying sessions. For the TGT cooperative gameplaying, a close simulation of the TGT structure was used. Specifically, students were stratified by their maths-ability level and gender, and then randomly assigned to a four-member team. At the beginning of each game session, students collaborated for 10 minutes in pairs, practicing with the game, discussing questions and solutions and correcting each other's misconceptions. For the remainder of the 30 minutes, class teams then competed against one another; each team member held a laptop and was assigned to a tournament table to play against representatives of the other teams. At any tournament table, the students were roughly comparable in achievement level. At the end of every two gaming sessions, the players at each table compared their gaming scores to determine their rank order which was then converted into points. The points that the players earned were added to compute a team score. The individual and team scores were ranked and listed in a newsletter, and distributed to the class at the beginning of every treatment

	week. In the newsletter, individuals were identified by pseudoidentities (IDs) known only to themselves and their teammates, which was intended to ensure the individual accountability in cooperative learning (by having each team be aware of its members' contribution), whilst avoiding interpersonal competition. During interpersonal competitive gameplaying, students were seated at their own desks and played games against the computer. At the end of every two gaming sessions, individual scores were compared against others in the class. Their individual percentile ranks, identified by their own names (so everyone could compare him/herself with other individuals), were announced in a newsletter every week.
所收集之 研究資料	pretest and posttest.
研究結果	1. The gameplaying was more effective than drills in promoting maths performance, and cooperative gameplaying was most effective for promoting positive maths attitudes regardless of students' individual differences. 2. Maths gameplaying did promote test-based cognitive learning achievement. Additionally, gameplaying context (TGT cooperative or interpersonal competitive) played a significant role in moderating the effect of educational gaming on affective learning outcome.
科技工具之特點	1. TGT cooperative gameplaying and competitive gameplaying shared the first two motivational features (fantasy and relevance), hence this would engage learners more than in the no-gaming group 2. Cooperative gameplaying helped socio-economically disadvantaged students more in terms of facilitating positive maths attitudes.

編號:灰七

Data Extraction Form	
欄位名稱	內容
文獻來源	Nguyen, D.M., & Kulm, G. (2005). Using web-based practice to enhance mathematics learning and achievement. Journal of Interactive Online Learning, 3(3), 1-16.
研究目的	This study was designed to explore (1) accessibility issues of the WebMA instrument at the middle school level, (2) the extent that web-based practice affects students' mathematics learning and achievement, and (3) the differences on students' achievement between web-based and paper-and pencil practice.
研究問題	
研究方法	This study took place in two different middle schools in Southeast Texas. Since the information gathered from the state report card on the diversity, end-of-course exams, and school classification and ranking were similar, they were combined for this study. There were 95 students from six math classes participating in the study. There were 50 seventh and 45 eighth graders; 41 were females and 54 were males. Students from the six math classes were randomly assigned to one of two treatment groups within each class. Half of the students in each class participated in Web-based Assisted Learning and Practice (WALA) and spent their in-class practice time in the school computer lab. The other half remained in the classroom and did paper-and-pencil practice – Traditional Assisted Learning and Practice (TALA) with their mathematics teacher during the homework practice time. These practice sessions lasted about 30 minutes each day, three times a week. The study was conducted in three weeks.
教學單元	■數與運算(Number & Operations) □代數(Algebra) □幾何(Geometry) □測量(Measurement) □資料分析與機率(Data Analysis & Probability)
教學主題	分數加減法
教育階段	□國小 ■國中 □高中 Middle schools: seventh and eighth graders.
融入教學之工具	Web-based Assisted Learning and Practice (WALA)
學習活動 (Learning activity)	教學策略： The WALA students did their practice homework in the computer lab under the supervision of the first author. They had the option to check if they got the correct or incorrect answer for each question. They also received adapted feedback for each answer, and the total score when they finished each assignment.
所收集之研究資料	Pre- and posttests、WALA Survey Questionnaire
研究結果	1. The mathematics achievement of students who participated in the web-based approach was significantly higher than that of their classmates who received the same items using paper-and-pencil. 2. The WALA students enjoyed working with the web-based tasks and desired to have more of this kind of interactive practice. 3. Students in the web-based group were provided with a new experience with computers to complete mathematics assignments, with help and feedback provided, and the opportunity of more practice for better scores. Those factors would ultimately affect the WALA results of having higher scores on the posttest by exposing them to more practice in comparison with their counterpart.
科技工具之特點	1. The randomized items with contexts changing on each assignment provided the opportunity for enriching practices. Students taking the web-based practice were able to take and retake each homework task as

	many times as they wished. Every time they retook each homework task, the wording or numbers used in the items as well as the required computational procedures were slightly different, but the mathematical content and concepts remained the same. Therefore, these students experienced a greater number of different items on the same mathematical procedures in various contexts. On the other hand, the TALA students perceived the alternative homework sets as additional work and were not motivated to complete them. 2. The immediate feedback was the most attractive feature of the web-based delivery instrument. The immediate response in this study not only let students know whether their answer was correct or incorrect but also provided students with adapted feedback and guidance, encouraging students to examine their own mistakes and adjust their procedures.

編號:灰八

Data Extraction Form	
欄位名稱	內容
文獻來源	Stohl, H., & Tarr, J. E. (2002). Developing notions of inference using probability simulation tools. The Journal of Mathematical Behavior, 21(3), 319-337.
研究目的	Our research sought to determine how technology tools enable and constrain students' development of the notion of inference from probabilistic situations. In this paper, we report how two students used software tools to formulate and evaluate inferences based on data randomly generated from simulations.
研究問題	1. How do these students use Probability Explorer tools to simulate experiments and analyze data as part of their meaning-making processes in solving a variety of probability tasks? 2. How do these students develop an understanding of the interplay of theoretical probability, empirical probability and sample size, and use these understandings and computer-based tools to formulate and justify inferences based on data?
研究方法	This research report focuses on two average-level sixth-grade students who participated in a larger study of 23 sixth-grade students in an average-level mathematics class in an urban, southern public middle school. Prior to instruction, in collaboration with the regular classroom teacher, we purposely selected Manuel (Hispanic male) and Brandon (Caucasian male) to serve as one of three case-study pairs. These students were chosen to reflect the ethnic and socioeconomic diversity within the class and were representative of average-level mathematical achievement based upon scores on standardized tests in mathematics as well as a pre-instructional test in probability.
教學單元	□數與運算(Number & Operations) □代數(Algebra) □幾何(Geometry) □測量(Measurement) ■資料分析與機率(Data Analysis & Probability)
教學主題	Probabilistic reasoning and notion of inferences in a variety of contexts with random phenomena (e.g., coin tosses, selecting marbles from a bag, catching fish from a lake).
教育階段	■國小 □國中 □高中 The public middle school: sixth-grade students
融入教學之工具	Software simulation tools: Probability Explorer software
學習活動 (Learning activity)	教學策略： ＊The design of each of our tasks included students use of PE tools for simulation, analyzing data, and making inferences based on data. Students to model the phenomena, carry out simulations using PE, and collect, display and analyze data in order to draw appropriate inferences and formulate convincing arguments based on data. 1. The first two tasks were designed to help students make connections between random events with familiar objects to the random events generated in PE. These tasks purposely posed questions to elicit students' intuition about fairness, randomness, and theoretical probability so we could build upon those intuitions in developing deeper understanding of probability concepts throughout the unit. These tasks also involved students in re-presenting the data; by hand and in PE in a variety of representations (e.g., bar graph, pie graph, pictographs, table). The students were able to use the representations to analyze the distribution of data and begin discussions about the role of sample size, number of outcomes (two outcomes with coins vs. six outcomes with a die) in the distribution and variation in results.

	2. After students had analyzed data from simulations with these first two tasks, we posed a task designed to provide students a situation with an unknown sample space. We intended for them to use simulations and data analysis to infer information about the contents of a bag of marbles when they only knew that the bag had x number of marbles and any number of six possible different colored marbles. We purposely designed the first part of the Mystery Marble Bag task with x = 10 marbles to promote students' use of percents or proportional reasoning to infer the contents of the bag. The second part of the task had x = 12 marbles to provide a situation in which proportional reasoning was not as transparent. In this regard, we would be able to distinguish whether students were actually using proportional reasoning to make inferences from data. As students worked on this task, it became apparent that only some students were using proportional reasoning, and that most students were using a technique that involved running simulations with the number of trials (n) equal to the number of marbles in the bag (x). This n = x strategy facilitated arguments based on small sample sizes. Thus, we needed to create a task that would induce a perturbation in the students' thinking about how to determine the number of trials to run and when they would know that they had collected enough data. The task we designed was the Mystery Fish in a Lake task. 3. In the Mystery Fish in a Lake task, students were challenged to determine the probability of catching a certain type of fish if they knew only that the lake had just been stocked with two types of fish for a fishing contest. Not only did the task have an indeterminate population size x, the students were asked to make inferences about a probability rather than merely the counts of each type of fish. Eventually almost all groups ran significantly large numbers of trials (e.g., 500 or more) and made informed and reasonably accurate inferences about the probability of catching a "Green Gill" fish. For most students, the Mystery Fish in a Lake task accomplished the goal of having students realize how collecting large amounts of data can allow one to notice trends in data and make inferences about the population in question. In the Designing a Model task, students were given a situation and had to build a model based on theoretical probabilities and use empirical data to test the "goodness" of their model. Thus, these two tasks together helped students develop an understanding about the bi-directional relationship between empirical and theoretical probability and the role of sample size in that relationship. We felt that having a robust understanding of this bi-directional connection was important in order for students to develop notions of inference. 4. The final task of the unit, Schoolopoly, posed a situation in which students were asked to investigate several die companies that were rumored to produce biased dice. Each group of students investigated a different die company using a PE file that was pre-designed to simulate rolls of a die. We purposely designed the files so different companies' dice were weighted with varying degrees of bias—some biases were easier to detect than others. Each group of students was charged with the task of investigating the company's die to: (1) determine if the die was fair, (2) recommend whether the school should buy dice from this company for the production of their Schoolopoly game, (3) provide convincing evidence (e.g., data, graphs) to support their recommendation, (4) make an estimate of the probability of obtaining each number on the die, (5) create a poster with information on the previous 1–4 tasks, and (6) present the poster and make an argument to support their claims to the class.
所收集之 研究資料	Manuel and Brandon's laptop computerwas connected to a PC-to-TV converter in order to video-record their computer interactions while

	microphones captured their conversations.We used video recording because it is particularly helpful in trying to access students' construction of mathematical understandings and it provided us with a direct record of how the students used the computer tools. For this paper, additional data gathered from the instructional sequence was used in the analysis. In particular, the whole-class video, students' written class work and homework assignments comprised the data corpus.
研究結果	Our research indicates that students' work with the instructional tasks and PE tools successfully fostered their ability to make appropriate inferences based on data. In particular, Brandon and Manuel's use of PE tools, coupled with social interaction, enabled them to make connections between simulation data (empirical probabilities) and weights in the Weight Tool or marbles in a bag (theoretical probabilities). Although there were certainly instances when their use of PE tools constrained their thinking, the tools more often enabled them to explore the various probabilistic situations in an open-ended manner. They were able to choose how many trials to run and which representations they wanted to use to analyze the data. The visual displays of data often gave them a focal point for discussions and were used to support their inferences.
科技工具之特點	Visual representations：PE tools (e.g., pie graph, bar graph, data table) provided visual representations of the data that facilitated their analysis, and helped challenge their initial beliefs regarding the die's fairness. They learned to value sample distributions generated from larger sets of data.