Exploring the Educational Impact of Cinderella and KeTLMS: Functional Enhancements and Practical Use Cases

Takuya Kitamoto
kitamoto@yamaguchi-u.ac.jp
Faculty of Education
Yamaguchi University
753-8513
Japan

Naoki Hamaguchi
hama@nagano-nct.ac.jp
Nagano College
National Institute of Technology
381-8550
Japan

Hisashi Usui
usui@gunma-ct.ac.jp
Gunma College
National Institute of Technology
371-8530
Japan

Masataka Kaneko
masataka.kaneko@phar.toho-u.ac.jp
Faculty of Pharmaceutical Sciences
Toho University
274-8510
Japan

Takeo Noda
noda@phar.toho-u.ac.jp
Faculty of Science
Toho University
274-8510
Japan

Abstract

The rapid advancement of information and communication technology (ICT) has reshaped mathematics education by shifting instruction from traditional chalkboard and textbook paradigms to interactive, technology enhanced learning environments.

This study forcuses two complementary ICT tools Cinderella, a dynamic geometry software, and KeTLMS, a smartphone based learning support system to explore their combined potential in fostering conceptual understanding, learner engagement, and pedagogical flexibility.

In this paper, we introduce two extensions to KeTLMS and provide a detailed account of their design and implementation. The first extension enables learners to enter mathematical expressions into a text box and have those expressions rendered directly within instructional diagrams, dynamically updating the figures as the learner works through practice problems. By leveraging this feature, students can verify the correctness of their inputs in real time as they progress through drills.

The second extension allows learners to manipulate elements of the on-screen diagrams directly and automatically populate the corresponding mathematical expressions into the text box. In contrast to the first extension, this functionality transfers data from the graphical representation back into textual form. This capability effectively replicates the experience of graph construction on paper tests within an E-Learning environment.

We deployed these enhanced learning materials in actual classroom sessions and collected student feedback regarding usability and perceived effectiveness via questionnaire. In this paper, we also present and analyze the results of that survey study.

1 Introduction

The rapid advancement of information and communication technology (ICT) has fundamentally transformed the landscape of mathematics education, driving a shift from traditional chalkboard and textbook instruction toward interactive, technology enhanced learning environments. Recent research highlights the proliferation of adaptive learning platforms, gamified content, and mobile applications as key drivers of student engagement and conceptual development. In particular, studies on dynamic geometry software have demonstrated its efficacy in fostering spatial reasoning and heuristic problem solving by enabling learners to manipulate geometric constructions in real time ([1]).

Among dynamic geometry tools, Cinderella stands out for its intuitive interface and robust visualization capabilities. Prior investigations in higher education settings have reported that Cinderella's real time feedback and exploratory features help students build deeper understanding of geometric relationships such as the locus of moving points or transformations under varying constraints beyond what static diagrams can convey ([2]). Moreover, empirical work has shown that integrating dynamic geometry into inquiry based curricula enhances students' ability to formulate conjectures and test hypotheses autonomously, aligning with contemporary shifts toward student centered pedagogy ([3]).

Concurrently, the ubiquity of smartphones and tablets has spurred interest in mobile based learning support systems that extend instructional opportunities beyond the classroom. Recent meta analyses indicate that mobile applications, when thoughtfully designed, can promote continuous engagement, immediate feedback, and seamless integration with face to face or remote teaching modalities ([4]). However, many existing platforms struggle with balancing rich interactive content and the input constraints of small screens, often limiting learners' ability to work with mathematical notation on the go.

In response to these evolving trends, this study examines the combined potential of Cinderella and the KeTLMS system – a smartphone centric learning support tool developed by Takato ([5]). KeTLMS features simple one dimensional formula entry, real time support for online lessons, and novel interface extensions such as embedded diagrams and interactive buttons. To investigate how these enhancements operate within authentic instructional flows, we have developed a suite of digital instructional materials ranging from guided exploration tasks to interactive worksheets that leverage KeTLMS's extended functions. We introduce several of these instructional materials and present the results of a survey administered to students who employed them in class. The survey findings indicate that these materials are useful for enhancing learners' understanding of mathematical concepts.

2 Overview of KeTLMS

In response to the growing diversity of learners' needs and the widespread use of mobile devices in education, KeTLMS has been developed as a flexible, smartphone centric learning management system (LMS). Created by Takato at the KeTCindy Center, KeTLMS is designed to streamline both instructional delivery and student interaction in mathematics education. This chapter presents an overview of KeTLMS, detailing its core design principles and key functionalities.

2.1 System Overview

KeTLMS is a web based LMS tailored specifically for smartphone users, eliminating the need for any dedicated software installation. Its intuitive interface ensures that learners can immediately engage with course materials without navigating complex menus or controls.

By prioritizing simplicity and responsiveness, KeTLMS allows students to focus on mathematical tasks rather than on system operation. Moreover, educators can rapidly deploy or update content, reducing administrative overhead and enabling real time adjustments to lesson plans. Together, these features establish KeTLMS as an accessible platform that bridges the gap between traditional classroom methodologies and emerging mobile learning trends.

2.2 Core Functionalities

KeTLMS supports a range of functions that collectively enhance the mathematics learning experience:

- **One Dimensional Formula Input** : Learners can easily enter and edit simple mathematical expressions via a streamlined input field optimized for touchscreen use. This functionality facilitates quick responses during live lessons and simplifies the submission of written work in both synchronous and asynchronous settings.
- **Web Based Access** : Operating entirely within the browser, KeTLMS bypasses compatibility issues across devices and operating systems. Educators and learners alike benefit from immediate access via any modern smartphone, tablet, or computer, reducing technical barriers to adoption.

The following chapters will delve into the design and evaluation of specific enhancements - namely, the extended embedding functions - and their impact on teaching practice.

3 Embedding Figures and Buttons and Their Utilization

In order to enrich the interactivity and pedagogical potential of KeTLMS, we have implemented extensions that allow authors to embed dynamic Cinderella figures and associated control buttons directly within course materials.

To implement this feature extension, we integrated KeTLMS with the instructional-material authoring systems described in References [6] - [9]. These systems enable arbitrary placement of interactive buttons and Cinderella diagrams within the instructional interface. For implementation details, the reader is referred to the cited literature.

This chapter details the design and implementation of two key features: (1) the mapping of mathematical expressions entered in text boxes into Cinderella graphs, and (2) the reverse mapping, whereby manipulations of points within a Cinderella figure automatically update

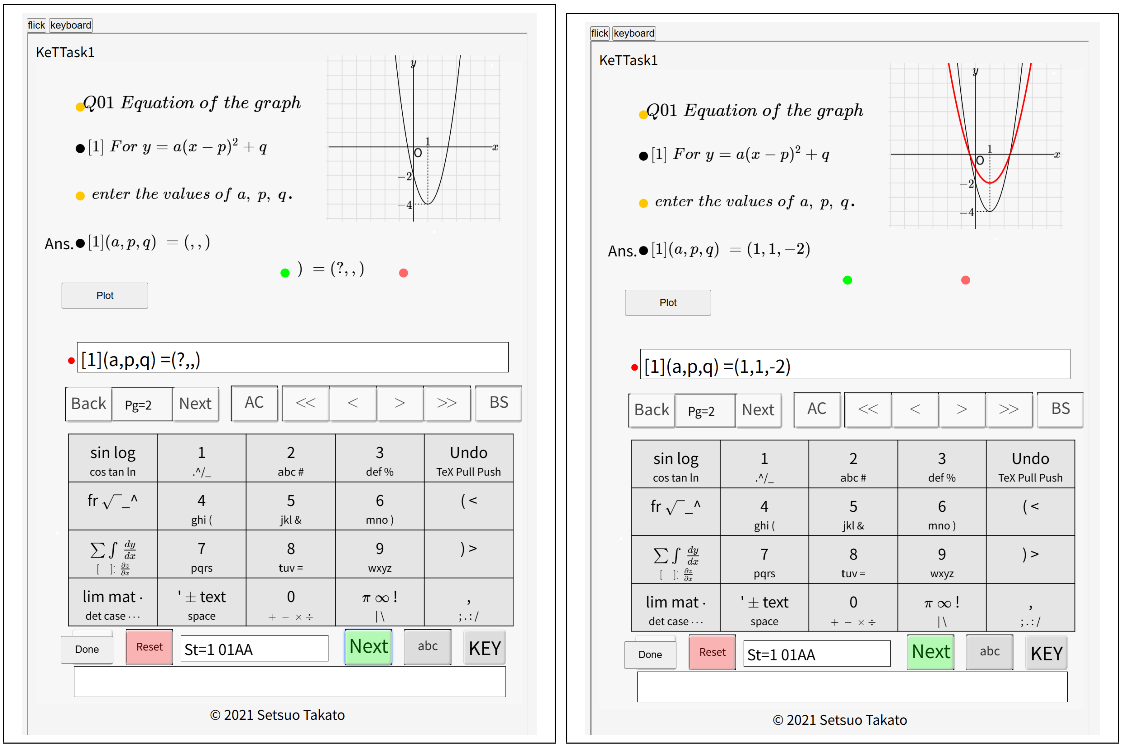

Figure 1: Reflecting Text Box Input in Cinderella Figures

corresponding text fields. Through these bidirectional linkages, instructors can create highly interactive worksheets that promote exploratory learning and provide immediate visual feedback.

3.1 Reflecting Text Box Input in Cinderella Figures

First, we describe the mechanism by which a formula entered into the text box is rendered as a diagram. Specifically, the user inputs a mathematical expression into the text field and then clicks the designated button; the system then automatically generates and displays the corresponding graph as a Cinderella diagram. A representative example is shown in Figure 1.

In the interface depicted in Figure 1, the user supplies values for the parameters a, p, and q in the text box immediately following the prompt "(a,p,q) $=$ ", and then activates the "Plot" button. Upon doing so, the system computes the corresponding curve and renders it within the Cinderella diagram. Figure 2 shows the result obtained when the values $(a, p, q) = (1, 1, -2)$ are entered and "Plot" is clicked; the curve $y = (x - 1)^2 - 2$ is displayed in the Cinderella canvas.

The core of this functionality is implemented in a JavaScript program, whose source is provided in Listing 1. In line 1 of that listing, the values entered into the central text box are retrieved and stored in the variable "abc". Lines 3 - 27 construct, in the variable "com", the sequence of commands required to instruct Cinderella to draw the diagram. Crucially, lines 6 - 8 integrates the contents of "abc" into these commands, thereby ensuring that the user's input is directly reflected in the rendered curve. Finally, the function call 'csdraw("c1",com)' executes the assembled commands and produces the diagram; the string "c1" refers to the identifier assigned to the on-screen Cinderella canvas.

Listing 1: Program for plotting the mathematical expression entered in the text box.

```
var abc = get_ketmath_input();

const [a2,p2,q2] = abc.replace(/\?/g, '').trim().slice(1,-1).split(',');

var com = `
a2=`+a2+`;
p2=`+p2+`;
q2=`+q2+`;
Ketinit();
Setparent(Cdyname()+"fig");
Setketcindyjs(["Nolabel=all","Color=offwhite"]);

Setax([7,"se"]);
a1=2;p1=1;q1=-4;
Plotdata("1","a1*(x-p1)^2+q1","x",["Num=200","dr"]);
Listplot("1",[[1,0],[1,-4],[0,-4]],["do"]);
Expr([[p1,0],"n2",text(p1)]);
Expr([[0,q1],"w2",text(q1)]);
Expr([[0,-2],"w2","-2"]);


Plotdata("2","a2*(x-p2)^2+q2","x",["Num=200","dr,2","Color=red"]);

Figpdf();
Windispg();
`;
csdraw("c1",com);
```

The client-side script is implemented in JavaScript so that, upon activation of the "Plot" button, the entered expression is parsed, the corresponding graph is generated, and communication with Cinderella proceeds without interruption. Because the source code is fully exposed, instructional designers may adapt the program's parameters and behavior to suit the pedagogical aims of individual lessons and materials, thereby enabling highly flexible and varied content creation.

This extension offers a major advance over traditional static materials by dynamically visualizing the relationship between symbolic expressions and their graphical representations. Learners benefit from immediate, on-demand rendering of their input formulas, which both deepens their grasp of mathematical concepts and fosters an intuitive understanding of how parameter changes affect curve morphology. In addition, the ability to produce graphs in real time supports formative feedback during classroom instruction and personalized learning pathways, thus contributing to improved educational outcomes.

In summary, the integration of interactive diagrams and control widgets significantly broadens the scope for ICT-enhanced instruction within the KeTLMS environment and represents a key innovation that enriches the experience of both content authors and learners.

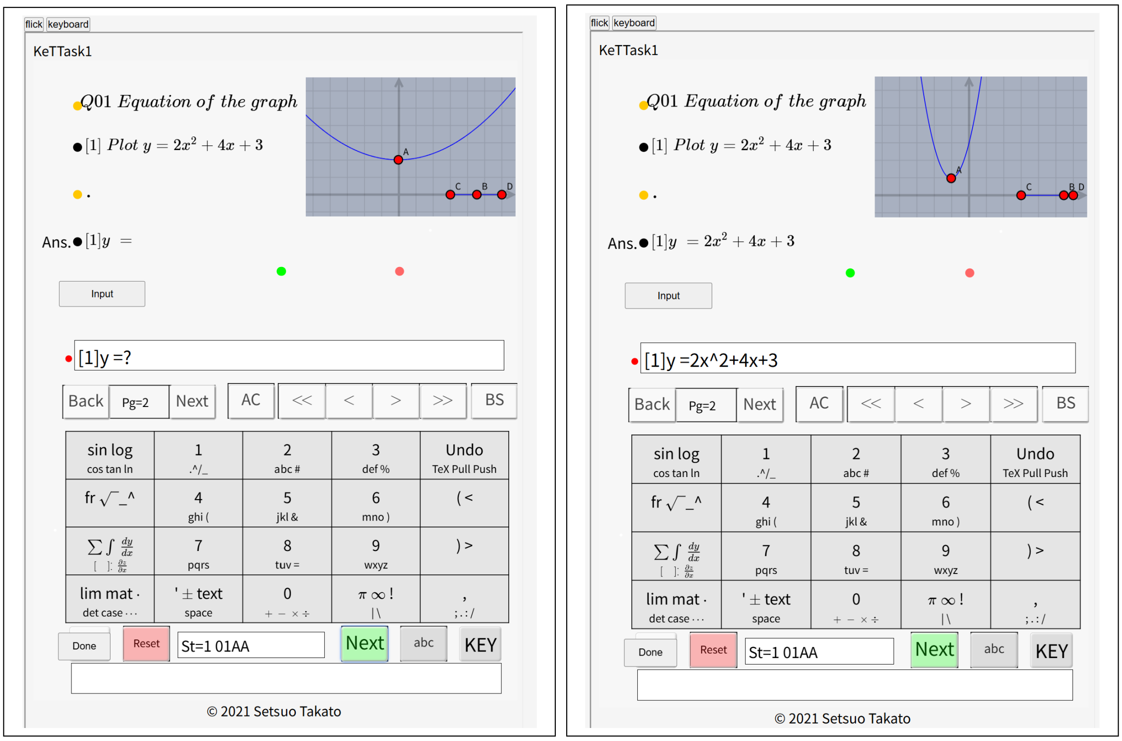

Figure 2: Populating Text Boxes from Figure Interactions

3.2 Populating Text Boxes from Figure Interactions

Next, we present the inverse operation, in which a user-adjusted curve in the Cinderella canvas is captured as a symbolic expression in the text field. As an illustrative example, consider the quadratic-curve exercise shown in Figure 2. In this module, learners manipulate the parabola's vertex (point A) and the coefficient a of the x^2 term – adjusted by dragging point B – so that the displayed curve coincides with the target equation $y = 2x^2 + 4x + 3$. Once points A and B have been repositioned to match the intended parabola, the learner activates the "input" button. This action automatically populates the text box with the equation corresponding to the diagrammatic curve. Figure 2 illustrates both the initial canvas and the state after adjustment and submission via the "input" control.

By employing such an interactive module, educators can author E-Learning tasks in which the student's answer is provided graphically, thereby broadening the scope of diagram-based assessment.

3.3 Educational Implications

These embedding features equip KeTLMS to deliver a truly interactive mathematics learning environment. By seamlessly linking symbolic input fields with dynamic graphical representations, students can iteratively test algebraic and geometric hypotheses and receive instantaneous visual feedback. This immediate feedback loop encourages self-guided exploration, allowing learners to build intuitive understandings of mathematical relationships through experimentation.

The system's accessible authoring tools further enable instructors – regardless of programming expertise – to develop and customize targeted worksheets that align with specific curricular goals. Consequently, KeTLMS fosters heightened engagement, reduces cognitive barriers inherent in translating between symbolic and graphical formats, and supports diverse learning styles. Collectively, these impacts contribute to accelerated conceptual mastery, sustained motivation, and more inclusive instructional practices in mathematics education.

4 Questionare and its analysis

We conducted a lesson using the instructional materials introduced above and subsequently administered a questionnaire to the participating students. In this chapter, we present the survey results and their analysis.

4.1 Assessment of Graph Comprehension

Respondents ($n = 30$) answered the question "Question1 : Did solving graph problems deepen your understanding of graphs?", using a four-point Likert scale. The results are summarized in Table 1.

Table 1: Responses to the impact of graph-solving on conceptual understanding

Response Category	Count	Percentage
Strongly agree	8	26.7%
Agree	20	66.7%
Disagree	2	6.7%
Strongly disagree	0	0.0%

Over 93% of participants reported a positive effect on their understanding of graphs.

4.2 Perceived Learning Gains

In Question 2, students provided free-text responses to the prompt, "Please describe the reasons for your answer to Question 1, including any impressions or comments." Analysis of free-text responses to Question 1 revealed three main themes:

- **Engagement through interactive experience.**
  "It felt like a game and was very fun."
- **Review and reinforcement of prior knowledge.**
  "I was able to review middle-school functions and graph problems that I had forgotten."
- **Intuitive grasp of formula-graph relationship.**
  "Substituted values were immediately reflected visually, so I could truly sense the behavior of the graph."

4.3 Usability of the Formula-Input Interface

In Question 3, participants were asked to provide free-form written feedback in response to the prompt, "Please share your impressions and opinions regarding the equation-input functionality of these instructional materials." Responses to Question 3 highlighted several usability issues:

- **Initial learning curve.**
  "The input operation was somewhat unconventional, and it took time to get used to."
- **Mobile-UI limitations.**
  "On a smartphone, interaction was difficult because the display did not fit the screen."
- **Ease of use once mastered.**
  "Once you understand how to use it, it's surprisingly easy, and the process of applying it is somewhat interesting."

4.4 Types of Devices Used to Access the Instructional Materials

In the final Question 4, respondents were asked which device they used to access the instructional materials (PC or smartphone). The results indicated that 12 students used a PC and 18 used a smartphone.

4.5 Summary

The quantitative and qualitative data together indicate that the interactive graph-solving and input module significantly enhances learners' conceptual understanding (93% positive) and engagement. To further improve usability, especially on mobile devices, we are going to develop on-screen guidance, larger input elements, and simplified syntax, which will help maximize the pedagogical benefits of this tool.

5 Conclusion

There has been growing interest in "living" instructional materials that allow students to actively manipulate dynamic geometry software. KeTLMS is an online authoring system that leverages the functionality of the dynamic geometry software Cinderella to create such materials. In this paper, we present extensions to KeTLMS and demonstrate the development of interactive learning resources.

First, we integrated dynamic geometry diagrams generated by the Cinderella software into our web-based platform. Second, we developed interactive learning materials that exploit bidirectional linkage between text-based formula entry and visual representations. By leveraging Cinderella's flexible graphical capabilities, learners can visually explore mathematical concepts and geometric objects, thereby reinforcing their understanding through the seamless coordination of symbolic and diagrammatic elements.

Looking ahead, several avenues for further enhancement are evident. User-interface refinements should be pursued to improve accessibility and ease of use. Moreover, the integration of generative AI techniques promises to automate content generation and offer adaptive, personalized feedback. In particular, a tighter coupling between Cinderella's dynamic visuals and advanced formula-input systems could yield an even more intuitive, practice-oriented learning environment. Concurrently, it will be essential to systematically collect and analyze instructor and learner feedback to iteratively refine both the materials and the underlying platform. Expanding the application scope beyond geometry – to other areas of mathematics and into interdisciplinary domains – also represents a valuable direction for future research.

Overall, this work constitutes a significant step toward transcending the limitations of conventional teaching methods by harnessing interactive visualizations within an integrated e-learning framework. By actively incorporating stakeholder feedback and deepening the synergy between our systems, we aim to realize a mature, practical toolset that robustly supports both educational practice and pedagogical research.

Acknowledgment

This work was supported by JSPS Grant in Aid for Scientific Research (C) KAKENHI 25K06706 and 21K02752.

References

[1] Segal, R., Oxman, V., and Stupel, M.. "Using Dynamic Geometry Software to Enhance Specialized Content Knowledge: Pre-Service Mathematics Teachers' Perceptions", *International Electronic Journal of Mathematics Education*, 16(3), 2021, em0647. https://doi.org/10.29333/iejme/11065.

[2] Nagy-Kondor, R..“Dynamic geometry systems in teaching geometry", *Teaching Mathematics and Computer Science*, 2(1). pp. 67-80, 2004.

[3] Rizos, I. and Gkrekas, N. "Is there room for conjectures in mathematics? The role of dynamic geometry environments", *European Journal of Science and Mathematics Education*, 11(4), pp. 589-598, 2023.

[4] Wei W., "Understanding and supporting the use of feedback from mobile applications in the learning of vocabulary among young adolescent learners", *Studies In Educational Evaluation*, 78(1):101264, 2023, DOI:10.1016/j.stueduc.2023.101264.

[5] Takato, S and Makishita, H, "Development of a Question Distribution and Answer Collection System for Mathematics Classes Using Only One Line of Text", *Proc. of The 29th Asian Technology Conference in Mathematics*, Yogyakarta, Indonesia, 2024.

[6] Kitamoto, T., Kaneko, M. and Takato, S., "E-learning system with Computer Algebra based on JavaScript programming language", *Proc. of The 23rd Asian Technology Conference in Mathematics*, Yogyakarta, Indonesia, 123–132, 2018.

[7] Kitamoto, T., Kaneko, M. and Takato, S., "Standalone web application for teachers to create teaching materials on a browser", *Proc. of The 25rd Asian Technology Conference in Mathematics*, Bangkok, Thailand, 258–267, 2020.

[8] Kitamoto, T., "Framework for building an E-Learning system using existing teaching materials", *14th MathUI Workshop 2023*, September 6-7,Cambridge, UK, 123–132, 2023.

[9] Kitamoto, T., Kaneko, M., Noda, M. and Kihara H., “E-Learning material creation system that utilizes existing teaching materials”, *Proc. of The 29th Asian Technology Conference in Mathematics*, Yogyakarta, Indonesia, 2024.