Feature Expansion of the Equation Editor in Mathematics Classroom Collaborator (MC^2) for Smartphones

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***Abstract*—This work-in-progress paper introduces new features for entering equations in Mathematics Classroom Collaborator (MC^2) for smartphones. Generally, in large first-year service courses in mathematics, students find it challenging to ask instructors or TAs questions and to communicate with other students compared to in other subjects. To address these challenges, MC^2 was developed as a mathematics chat system to facilitate mathematics communication and collaboration. In this research, to more effectively communicate using equations in a smartphone environment that students mainly use, we added an equation editor function using a math input interface named MathTOUCH, which allows students to enter equations by converting colloquial-style linear strings using AI without having to learn grammar like LaTeX. MathTOUCH has also been improved to be compatible with smartphones. This feature expansion is expected to make it easier for novice students in mathematics to ask questions to instructors using the chat system MC^2.**

***Index Terms*—STEAM education, mathematics education, communication tools, mathematical expressions, mathematical input interfaces, mobile learning**

I. Introduction

As a result of the growing demand for science, technology, engineering, and mathematics (STEM) skills to address many global challenges, the need to improve STEM education has increased worldwide [1]. In addition, since the early half of the 21st Century, STEAM (Science, Technology, Engineering, Arts, and Mathematics) education has been widespread worldwide as a new pedagogy in response to the need of educators to reinvigorate the role of creativity and innovation in STEM fields [2]. Both pedagogical approaches aim to renew scientific literacy, but student creativity receives more attention as a key skill in STEAM education [3].

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To support creative skills development in the young generation, Davies et al. [4] reported that factors such as flexible use of space and time, working outside the classroom/school, respectful relationships between teachers and learners, opportunities for peer collaboration, and awareness of learners' needs are important. Effective learning environments using information and communications technology are vital to promoting such learning activities. During the COVID-19 pandemic, the education environment changed radically, and the use of IT infrastructure, such as LMSs, and online communication tools, grew rapidly. Accordingly, student-teacher and peer-to-peer communication using online communication tools such as Microsoft Teams and Slack increased dramatically. However, in the mathematics education field challenges remain in communicating with learners.

The general lecture style of mathematics, especially in the large first-year service courses, is that instructors write math on a chalkboard, and students copy it down onto their notes [5]. Students rarely ask teachers or TAs questions and do not communicate with other students. Pollanen et al. [5] indicated that the factors of this problem include math phobia, dualism, classroom interface, and lack of democracy. To overcome these issues, they proposed *Mathematics Classroom Collaborator (MC^2)* that allows students to anonymously ask and collaborate with small groups, and enter mathematics easily to address these challenges. MC^2 is a chat application that allows users to enter mathematical expressions, and students can enter mathematical expressions using LaTeX style or using the mathematical editor. This original editor is a powerful tool, but there are some challenges for smartphone usage because smartphones have a limited display area for editing equations. In this work-in-progress paper, we present the feature expansion of the equation editor using a math input interface named MathTOUCH to improve the usability of MC^2 in smartphone usage. MathTOUCH allows students to enter equations by converting colloquial-style linear strings using

AI. This characteristic is promising to enhance usability even in the smartphone environment.

II. MC^2: Mathematics Classroom Collaborator

MC^2 is a mathematical online communication tool proposed by Pollanen et al. in 2017 [5]. As mentioned in the previous section, in large mathematics classes, it is hard for students to ask questions to teachers and TAs. To improve this situation, MC^2 was developed. MC^2 aims to aid students who have difficulty being actively involved in large classes communicate with teachers and TAs without hesitation.

Fig. 1 represents the screenshot of the original MC^2. It was developed as a web application based on node.js. Therefore, students can easily access it without having to pre-install anything. On the surface, the chatroom interface design followed a familiar texting application such as Telegram, Google Hangout, or WhatsApp to ease the learning curve [5]. As shown in the right figure of Fig. 1, the chat area of MC^2 is available for MathJax[1], a JavaScript library to represent equations written in LaTeX, MathML, and ASCIIMathML in the Web browser. An area for entering and sending messages that includes buttons to call tools for special input aids such as mathematical formulas is located at the bottom of the chat room area. However, it is hard for novice students to enter mathematical expressions using LaTeX format. Therefore, MC^2 provided an image upload function, which allows students to upload images of handwritten-mathematics on a piece of paper and a mathematical editor function. The original MC^2 has the diagrammatic equation editor as a mathematical editor function. This editor supported UI principles developed in [6], [7]; it allows placing mathematical symbols, which can be selected from menus or the keyboard anywhere and can be selected, moved, and resized. The completed mathematical expressions can be recognized using a baseline structured approach [8] and converted to TeX. The standard mathematics interface for novices is well-known as a structure-based input interface, such as an editor introduced in Microsoft Office. This method allows users to enter mathematical expressions by constructing symbol icons or mathematical structure templates. At first glance, the structure-based method supports easy input, even for novices. However, this input method requires users to understand the structure of equations first and construct mathematical elements according to the order of structure, which is different from the order of handwriting. This input process is not easy for novice students. On the other hand, the diagrammatic equation editor of MC^2 supports creating mathematical expressions in the same order as they would write them on a piece of paper. However, the results of the performance evaluation experiment showed some challenges for having to be precise on the position of each character and difficult to move each element [9]. These challenges have a high impact on using MC^2 on a smartphone because the display of smartphones is limited compared to the PC environment. In addition, the chat room is a text-area element of HTML, so inserted mathematical expressions in the text-area are represented by LaTeX-style text. However, LaTeX-style text is difficult to understand for novice users. This issue needs to be addressed to improve novices' usage.

[1]https://www.mathjax.org

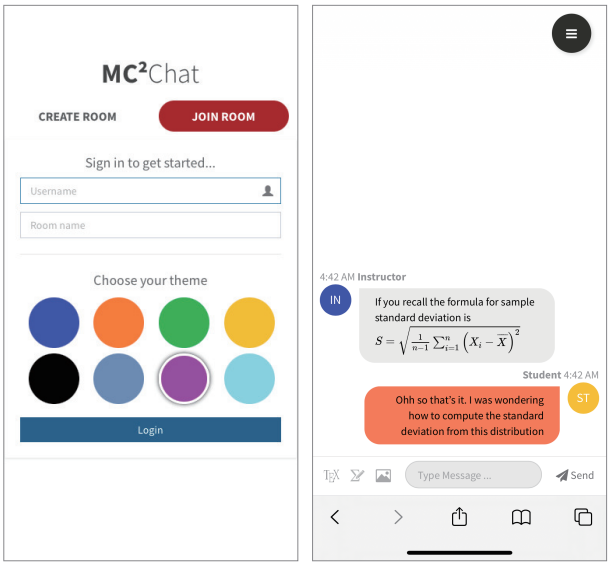

Fig. 1. Screenshot of original MC^2 Chatroom. The left figure is an initial login page, and the right one is a chatroom page. Users enable to enter equations as well as text on the send message area at the bottom of the chat room area.

III. Feature Extension for Entering Equations with Smartphones

In order to enhance the MC^2 environment for smartphone usage and provide several input methods for student preference, we implemented the MathTOUCH interface into MC^2.

A. MathTOUCH

MathTOUCH is a math input interface that allows users to enter mathematical expressions by selecting equation candidates produced by a predictive conversion method from ambiguous text for a formula. The original concept had been proposed by Fukui, one of the authors, in 2012 [10]. Fig. 2 shows the procedure to enter $\sqrt{\frac{1}{n}}$. Firstly, users enter a colloquial-style linear string for a mathematical expression. The colloquial-style linear string consists of LaTeX-like keywords corresponding to elements of the desired mathematical expression in order of reading mathematical expressions. For example, $\sqrt{\frac{1}{n}}$ is represented by "`\sqrt{\frac{1}{n}}`" in the case of LaTeX style. The brackets for delimiter are needed to represent the denominator and numerator. However, in the case of the colloquial-style linear string, users do not need to use invisible power signs and brackets as a delimiter, so users just enter "root1/n" as shown in Step 1 of Fig. 2. After that, equation candidates are generated by the predictive conversion algorithm, which is similar to the structured perceptron of natural language processing [11], [12] (Step 2 in Fig. 2). Finally, users select the desired equation from the candidate list. The completed mathematical expressions can be output in LaTeX, MathML, JPG, EPS, and several computer algebra systems

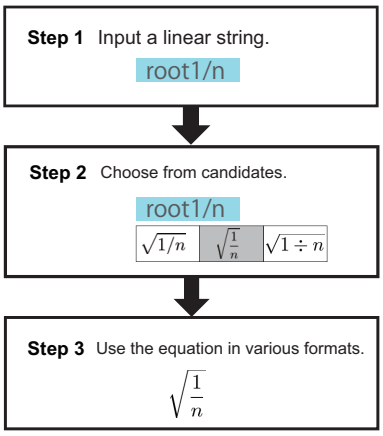

Fig. 2. Entering procedure using MathTOUCH.

syntax (Mathematica, Maple, and Maxima) styles. To date, we have focused on math online test systems, and we have continuously improved MathTOUCH for math e-learning and evaluated its effectiveness [13].

B. Implementation of MathTOUCH

In this study, we focused on the communication system, we have expanded the interface of MathTOUCH for smartphones to implement it into MC^2 so that it allows users to enter sentences containing mathematical formulas when sending messages in a chatroom. This feature expansion in this study was achieved through joint work between the MC^2 development group and the MathTOUCH development group. Specifically, we have added the MathTOUCH source code directly to the MC^2 source code and implemented it so that it would work smoothly. Fig. 3 is a screenshot of entering an equation using MathTOUCH in the chat room of the MC^2. If users touch the math input button, the MathTOUCH interface scrolls up from the bottom of the screen, the same as the native keyboard. Therefore, users do not need to switch screens to enter equations. MathTOUCH's soft keyboard, compatible with smartphone screen sizes, allows users to input linear strings of mathematical expressions with fewer touches than in LaTeX format, and math input is completed by simply touching the desired candidate predicted by AI. In the example trying to input $S = \sqrt{\frac{1}{n}}$ in Fig. 3, candidates for the "1/n" part are displayed. Various special symbols are also able to be entered while switching the display on the soft keyboard.

In addition, regarding the issue of the textarea does not supporting two-dimensional mathematical expressions, we changed the textarea to the DIV element, which is contents editable in HTML to render the entering equation with LaTeX-style as soon as it is inserted using MathJax. If students want to modify the inserted mathematical expressions, they just tap it, then the MathTOUCH editor scrolls up and they can edit the equation.

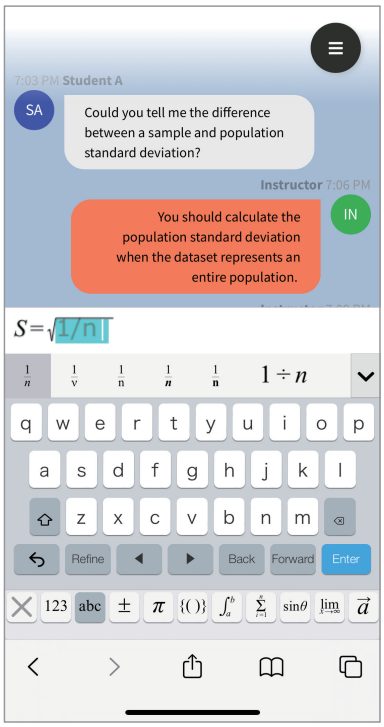

Fig. 3. Screenshot of the MathTOUCH interface implemented in MC^2.

IV. Conclusion and Future Work

This work-in-progress paper introduces feature expansion about entering equations of MC^2, which is an online real-time communication tool for the mathematics classroom. To strengthen the mathematical expressions environment of MC^2 for smartphones, we implemented MathTOUCH, which is an intelligent math input editor using AI. Further consideration will be needed to improve the predictive accuracy of MathTOUCH, evaluate the usability of MathTOUCH in MC^2, and conduct an empirical study using MC^2 in a real mathematics classroom.

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