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Chapter 2
Classroom Learning Partner: Pen-based Software For Creating and Sharing Visual Representations

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Abstract A You-Try-It session at CPTTE 2016 provided hands-on experience with Classroom Learning Partner (CLP), a pen-based classroom interaction system whose goal is to improve STEM teaching and learning by supporting the creation and sharing of visual representations. Participants played the role of students in an elementary math classroom, using CLP's digital tools to create visual representations for multiplication and division problems. They also were able to view the teacher's version of the software, which provides information about students' use of the digital tools, with the goal of providing teachers with insights into students' mathematical thinking.

2.1 Context and Motivation for CLP

The goal of CLP is to improve STEM teaching and learning by supporting real-time use of student work created via a pen interface. It accomplishes this goal by means of a create, interpret, share interaction model: Students use a tablet pen to create representations; CLP employs AI methods that interpret the representations, when possible, in order to provide the teacher with feedback about student understanding and to enable the teacher to filter and sort the representations based on CLP's

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interpretation and on her own assessment; the teacher then can select student work to share as a basis for class discussion and to identify students who may need help.

In its early days, CLP employed Classroom Presenter [3] as its underlying infrastructure and was used in introductory undergraduate computer science and chemistry classes. Its digital ink interpretation routines focused on recognizing handwritten text strings and sequences, identifying shaded and enclosed regions, and recognizing sketched representations such as box-and-pointer (aka linked list) diagrams or chemical structures. CLP has been re-implemented several times, and for the past six years, new software tools have been developed for use in elementary school science and math classes. (See [4, 5, 6, 7, 8, 9, 10, 11, 12] for details of CLP's design, development, and use in classrooms.)

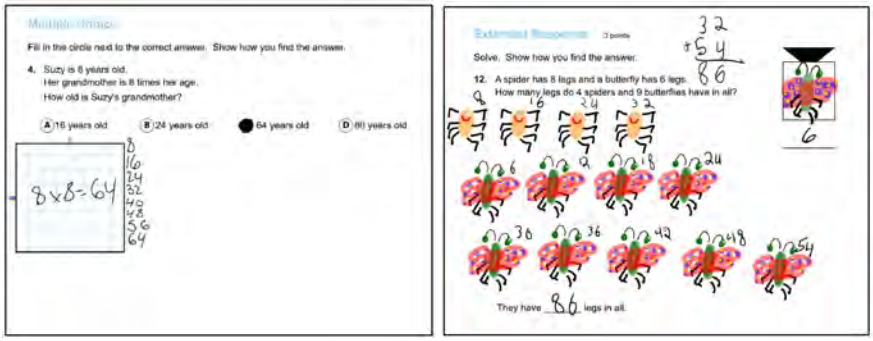
2.2 Current Work

Most recently, CLP has supported research projects aimed at improving upper elementary teaching and learning of multiplication and division, *INK–12: Teaching and Learning Using Interactive Ink Inscriptions in K–12*; and mathematical argumentation, *Technology For Mathematical Argumentation*. Videos describing CLP and the projects can be found on each of the project websites [1, 2] and. CLP's create, interpret, share interaction is illustrated in more detail on the INK–12 website's model of interaction page [1].

CLP is organized around the idea of an electronic notebook that contains lesson *pages*, along with digital tools for working through lesson problems on the pages. In the INK-12 project, current lessons focus on upper elementary math, and CLP's tools include not only digital ink but also tools that enable students to easily and quickly create visual representations using common mathematical constructs, such as arrays and number lines, and other novel tools designed to support new kinds of visual representations. In designing each tool, the goal was to balance freehand drawing with structure in order to support both students' creative expression and machine interpretation. Examples of student work created using CLP's array and stamp tools are shown in Figure 2.1.

2.3 Session Overview

After a brief introduction to CLP, participants played the role of students, using CLP's tools to solve and explain multiplication and division problems by creating and manipulating visual representations. They also were able to view the teacher's version of the software, which provides information about students' use of the digital tools. Additionally, we discussed findings from our classroom trials.



(a) Using an array to solve 8 x 8 (b) Using a stamp to solve 8 x 4 + 6 x 9

Fig. 2.1: Examples of student work created using CLP's array and stamp tools

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