Development and Application of a Web-based Programming Learning System with LED Display Kits

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ABSTRACT
This paper describes a new programming learning system. It consists of a Web-based flowchart application and Light Emitting Diode (LED) display kits. The LED kits produce various animations or static images according to a flow chart. The flowchart tool allows students to manipulate program elements through a Graphical User Interface (GUI). Survey results show that the proposed system makes learning how to program less challenging and more interesting for beginners. Encouraged by these initial findings, the authors are developing a system with add-on features including sensor accessory options and compatibility with well known LEGO® products.

Categories and Subject Descriptors
K.3.2 [Computer and Information Science Education]: Computer Science Education

General Terms
Algorithms, Experimentation

Keywords
Programming, Flowchart, Web-based Learning, LED Display Kit

1. INTRODUCTION
Early programming education helps nurture prolific and creative software developers who can make significant contributions to our increasingly information-centric global economy. Teaching beginners how to program presents a great challenge since a student must have an experience that goes well beyond simply learning the syntax of a programming language. However, students tend to spend most of their time struggling with syntax errors rather than solving a problem [6].

Students of non-English speaking countries have even more difficulty in becoming skillful in programming languages such as Visual Basic, C or Java, because they are forced to write their programs using English statements and reserved words. Therefore, a visual programming language based on flowcharting may greatly improve their learning effectiveness by allowing them to bypass some of the language-related obstacles as a non-English speaking person.

Several tools provide flowchart-based programming environments [2, 3, 5, 7, 10]. All these tools claim that they are effective in reducing the cognitive burden of programming learning by shrinking the conceptual distance between actions in the real world and programming. Among them, RAPTOR [3] allows students to create programs by combining basic flowchart symbols and an environment that visually displays the location of the currently executing symbol and the contents of all variables. RAPTOR has many new features compared to its predecessors. Nevertheless, the existing tools including RAPTOR are designed mainly for college students and inappropriate for K-12 students.

This paper introduces a new programming learning system geared toward K-12 students and the students of non-English speaking countries. The learning system consists of a Web-based flowchart application and an LED display kit. Students can display static outputs (e.g., LED lights turned on diagonally from left to right) or animations after creating a flowchart by dragging and dropping icons representing different program elements. The LED display kit acts as an output device that displays images according to a set of instructions automatically generated by the online flowchart program. Our system adopts the problem-based learning (PBL) approach [8] that encourages students to solve a well defined problem and to learn on their own during their attempt to find a solution to the problem.

The remainder of this paper is organized as follows. The LED display kit is described briefly in section 2. Section 3 discusses our fully developed Web-based flowchart application. Section 4 presents the results of our survey administered among diverse student groups to measure the effectiveness of our new programming learning system. Section 5 concludes this paper with a discussion of our future research plan.

2. LED DISPLAY KIT
A light emitting diode (LED) is a semiconductor diode that emits light when electrically biased in the forward direction of the p-n junction [9]. Nowadays LEDs are popular in many applications such as traffic signals and electronic display boards due to their...
The LED display kit consists of an 8×8 LED matrix panel, a microprocessor (CPU), and a serial communication module. Figure 1 shows the system architecture of our LED display kit. The LED display kit, an 8×8 dot matrix produces a visual output as instructed by the code generated by the Web flowchart application.

![System Architecture of the LED Display Kit](image)

**Figure 1. System Architecture of the LED Display Kit**

Each row of the 8×8 LEDs represents 8 bits in a binary number system, and thus it can display values between 0 and 255. For instance, assuming that an input number of the LED display kit is 1001111₂, the corresponding row of the LED panel is lighted as follows: on, off, off, off, on, on, off, and on). Note that the LED panel has 64 LEDs, and therefore the LED display kit can produce \(2^{64}\) different patterns. Figure 2 shows an example (letter X) of the many possible outcomes and a photo taken during a programming class in an elementary school.

![LED Display Kit and Programming Class](image)

**Figure 2. LED Display Kit and Programming Class**

Although the program output can also be displayed to a standard monitor, using the LED display kit has many advantages over the use of a regular computer screen due to the following reasons:

- Students appear to be much more engaged in their activities when they instantly see, on our LED display kit, the results of algorithms they create via the Web flowchart tool. Particularly, the LED display kit seems to invoke the curiosity of the students due to its novel appearance.

- Students can also arrange multiple LED display kits into a bigger display to produce a mosaic effect, more complex shapes, or animations. This feature of the LED display kit encourages collaborative learning and is not possible when using a computer monitor.

3. WEB-BASED FLOWCHART SYSTEM

The Web-based flowchart system (also referred to as Web-flowchart) has been implemented in Microsoft Visual Basic 6.0 and HTML 4.0. The core ActiveX module of the flowchart system is automatically downloaded into client computers when users visit our programming education Web site (http://www.ilogic.kr) for the first time. The Web-flowchart supports basic programming constructs such as variables, if/else, loops, one-dimensional arrays, and functions. We developed two courses using the proposed system: one for beginners and the other for advanced users. In the beginner’s course, a learner is allowed to use only the first row (8 dots equivalent to 1 byte of information) of the display apparatus and a wait-timer command. Each physical LED light can be turned on by either selecting the check boxes in a Web-flowchart LED icon or using a variable initialized with a value. With this basic setup, students can already create a simple animation. For example, they can make a dot move from right to left by continuously multiplying a value (e.g., 1) in a variable by 2. The speed of the dot movement can be controlled by a wait-timer in milliseconds. To code this animation, students do not need to know any special print command syntax (e.g., one used in Java or C programming language). Therefore, students can just focus on the logic of the algorithm behind the animation, receive instant feedback, and become familiar with core programming concepts more easily. In the advanced course, a learner can use all eight rows (64 dots) of the LED display kit, which leaves much more room for creativity.

The use of variables in computer programming is one of the common weaknesses of novice programmers [7]. In the Web-flowchart environment, students use symbols that represent variables (□, ○, △, ☆, ◆, and ♦) for simple calculations and can produce still images or animations after creating a flowchart in a drag-and-drop fashion. Figure 3 shows our Web-based flowchart system and an algorithm that displays a triangle.

![Web-based Flowchart System](image)

In conjunction with our programming education system, we also adopt the problem-based learning (PBL) approach [8]. As part of this effort, we developed a comprehensive set of programming challenges (6 for beginners and 15 for advanced users) that encourage students to use their imagination and creativity.

These problems include asking students to:

1. Create a flowchart for the LED lights to be turned on diagonally from left to right,
2. Create a flowchart for the LED lights to be turned on diagonally from right to left,
3. Create a flowchart for the LED lights to be turned on in an X shape, that is, the combination of (1) and (2), and
(4) Create a flowchart for a triangle rotating clockwise.

Figure 4 shows students collaborating to do a group assignment.

4. SURVEY

This section describes the results of surveys administered in various programming classes from Fall 2005 through Spring 2009. The programming courses were offered for diverse groups of students including elementary school students, gifted students, college students, and teachers. As part of this pilot project, we designed a prototype LED display kit and made 20 copies of it. The first year (beginner’s) programming course was tried at the Sin-sang-do elementary school and Woo-i elementary school during the Fall 2005 and Spring 2006 semesters respectively. Approximately, 35 students attended the 30-hour programming course during 15 weeks (2 hours per week), and one LED display kit was shared by two students.

For the second year (advanced) programming course, we modified the LED display kit and made 85 of them. The course was offered at the Sin-sang-do elementary school and Joong-ang elementary school during the Spring 2007 semester simultaneously. The course outline was the same as the first year course. We developed our own textbook that introduces programming concepts and describes how to use the Web-flowchart tool and LED display kits. The textbook consists of 3 parts: basic concepts for programming, Web-flowchart, and PBL-based algorithm exercises.

4.1 Elementary-School Students

We have 2 year experience of teaching at three elementary schools from Fall 2005 through Spring 2007. A total of 126 elementary school students participated in our programming courses. At the end of each course, student feedback was collected in the form of written answers to the following questions:

(Question 1) Do you think that our programming course using the Web-flowchart tool and the display apparatus is interesting?

(Question 2) What is your opinion about our problem-based learning (PBL) approach in which an instructor assigns challenging problems (e.g., animation problems) to students, and then students try to solve the problems using the display apparatus and Web-based flowchart tool?

(Question 3) Do you think that these programming education tools helped you understand programming concepts or algorithms?

(Question 4) Are you going to take a more advanced programming course again next semester?

(Question 5) Are you going to recommend this programming course to your friends?

The survey results of the 126 students are shown in Figure 5. The figure shows that the programming learning method using the LED display kits and the Web-flowchart tool is engaging students and helping them understand programming concepts or algorithms.

4.2 Undergraduate Students

We also offered our programming course to undergraduate students during the Fall 2007 semester. A total of 35 students attended the 8-hour programming course during 4 weeks (2 hours per week). The students who took the
course were all seniors from the department of computer education at Seoul National University of Education (SNUE). The course was offered as part of another course on topics in elementary school computer education. Seventy percent of graduates from SNUE become teachers at 500 public schools in Seoul city. The course was intended to prepare the seniors for being able to teach elementary school students how to program. Most of the students stated that the course was interesting, and that they would be able to reuse the course materials in teaching their students in the future.

4.3 Teachers
Ten elementary school teachers also took our programming course. These teachers were all enrolled to a Master degree program in Computer Education at SNUE. There were 2 male and 8 female teachers. They attended our 6 hour programming course during the Fall 2007 semester. Before taking the class, the teachers already had some basic understanding of programming concepts and could solve programming problems with moderate difficulty level. However, they were having difficulties in teaching programming to their students. Five (1 male and 4 females) out of 10 teachers who took the course responded to our survey.

The respondents had to use a number between 1 (the lowest score) and 4 (the highest score) to answer each of the 5 questions on our programming learning method using the LED display kits. The five questions used for our survey are shown below:

(Questions 1) Do you think our programming education approach using the LED display kits was interesting?
(Question 2) Do you think the Web-flowchart system was easy to use?
(Question 3) Do you think teaching how to program is necessary for elementary school students?
(Question 4) Do you think the PBL-based programming teaching method will help students develop creative thinking skills?
(Question 5) Will you offer a programming course using our LED display kits at your school next semester?

Table 1: Results of the Survey Administered to Teachers

<table>
<thead>
<tr>
<th></th>
<th>Very positive</th>
<th>Positive</th>
<th>Negative</th>
<th>Very Negative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Q2</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Q3</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Q4</td>
<td>0</td>
<td>4</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Q5</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

4.4 Gifted Students
The same programming course was made available for gifted students at the SNUE Gifted Institute during the Spring 2008 semester. A total of 33 gifted elementary school students participated in the programming class. 12 students from an advanced science program and 11 students from the institute’s advanced math program attended 3 hours of the programming class. They were either 5th or 6th graders. Most of those who took the class had prior experience in programming in Visual Basic or C. Students were engaged in learning basic Web flowchart uses and concepts and given five problems sequentially. The difficulty of each question increased as they solve their problems. Students who solved all five problems received 5 points while those who solved 1 problem received 1 point.

The grader also assigned a score ranging from 1 to 5 based on his/her subjective evaluation of a student and the student’s participation level (e.g., their attitude, the questions they asked, and how responsive they were) in class. Table 2 shows the evaluation results of the students. The advanced math group had higher overall GPA than the advanced science group. However, the science group students participated in the class more actively, and they therefore demonstrated superior ability to solve the given problems.

Table 2: Evaluation Results of the Gifted Students

<table>
<thead>
<tr>
<th></th>
<th>Problem-Solving capability</th>
<th>Class Participation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science-intensive class</td>
<td>3.5</td>
<td>4.58</td>
</tr>
<tr>
<td>Mathematics-intensive class</td>
<td>3.25</td>
<td>4.38</td>
</tr>
</tbody>
</table>

5. CONCLUSION AND FUTURE WORK
This paper proposed a new programming learning approach using an LED display kit and a Web flowchart tool. We tested the system with various audience groups in a number of courses. The responses from our in-class surveys were generally positive.

We are planning to add the following new features to the learning system we discussed in this paper. The first set of new features will include infrared, touch, and other sensors as well as sound and mobility. We are also investigating the feasibility of introducing a new interface so that combining our system with LEGO® blocks and an NXT robotics kit is possible. Figure 6 shows different possible combinations of the LED display kit and the existing LEGO® products.
6. ACKNOWLEDGMENTS
We would like to thank three teachers, Soo-Poong Chae at the Woo-i elementary school, Jin-Sook Ryu at the Sin-sang-do elementary school, and Ju-Hwa Lee at the Sin-bong elementary school for teaching the programming courses and administering student surveys in their classes.

7. REFERENCES


