

TEACHING INTRODUCTORY PROGRAMMING THROUGH REUSABLE LEARNING OBJECTS: A PILOT STUDY

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ABSTRACT

This paper describes a pilot study that examines the perceived effectiveness and usability of a dynamic reusable learning object that enriches lecture material in an introductory programming course. In particular, we focus on the topic of looping by providing students an interactive tool that lets them simulate and review the execution of code. The results suggest that students in CS0 courses may utilize this tool for learning about looping, while CS1 students are more likely to use it for reviewing concepts that they learned in class. The findings of this pilot study have enabled us to focus on which aspects to improve for the next set of reusable learning objects.

INTRODUCTION

The main goal of this project is to create a series of reusable learning objects (RLOs) [1] to reinforce the material typically discussed in introductory programming courses by addressing each topic with multiple delivery methodologies designed to leverage different learning styles [4].

Generally the resources available to students learning how to program are limited to the instructor, the book, and any material that can be found online. The problem with online material is that it is often of poor quality, and not always adaptable to the material discussed in lecture or in lab. Through this project we are creating both static and online content that will help the students review material discussed in class. The approach to utilizing RLOs for computing and especially programming education is not new. Costelloe, Sherry and Magee created a RLO that focused on arrays, reporting that students found it helpful, fun, and that they learned from experience [2]. Fossati et al. explored a similar topic when they created an interactive learning tool for pointer-based lists, reporting that the tool is effective and improving so much that it may nearly substitute the work of human tutors [5]. A report of the research by Emurian et al. also hints that these types of online systems may replace tutoring services, thus confirming the ability of rich environments to assist students in learning computer programming [3]. Although their research was not focused on the computing domain, Salajan et al found that the visual and interactive features that are integral components of these types of tools have significant potential to inducing positive outcomes when students are learning concepts that are difficult to envision [6]. Programming concepts are often abstract and difficult for students to grasp since they lack the associated experience. Thus, using RLO's should be beneficial to improving student learning in introductory programming courses.

PROJECT DESCRIPTION

The research reported in this article was gathered as part of a pilot study aimed at assessing the feasibility of a more complex and encompassing project in the future. Our approach aims at enhancing introductory programming courses by enriching the resources available to students. Each course topic will be explored by a series of content modules, each composed of five learning units. Each learning unit is designed to target different learning styles (visual, auditory, kinesthetic), and to offer multiple ways for students to review the material discussed in class. This approach is depicted in Figure 1.

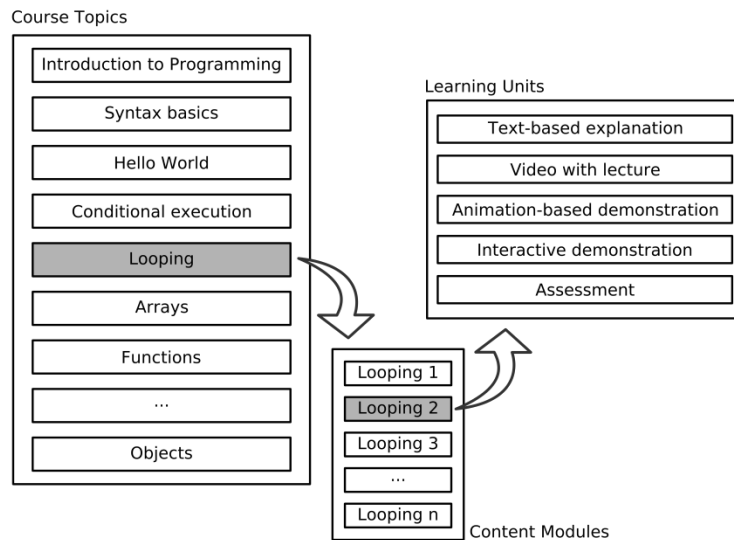


Figure 1: Overview of the project's structure

This article is a pilot to understand some of the best practices using RLOs in a computing course and to also serve as a basis for the larger overall aim. Applying the lessons learned and initial feedback from the pilot study, we intend to enhance each student's experience by leveraging different learning styles through a variety of content delivery methodologies, through text and video-based lectures, and to assist disaffected students by offering engaging and dynamic content. The long term goal of our RLO project is to develop learning content in this context so that students can gain a greater understanding of the material, improve their performance on exams and assignments, and report a better performance in subsequent courses. Moreover, the department will have standardized material that can be utilized by any student of any section of introductory programming courses, static and dynamic content that any introduction to programming instructor can utilize to enhance lectures, and a set of examples and narratives reviewed by various instructors. In addition, this material can be utilized by secondary education institutions, other colleges and universities, and individual learners.

Assume that you are working with three variables: xValue, yValue, and zValue.
Assume that all three variables have been initialized to 0 (zero).

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0) for ( int c = 0; c < 5; c++ )
1) {
2)     xValue = c;
3)     yValue = yValue + xValue * 2;
4)     zValue = xValue * yValue;
5) }

```

xValue: 0
yValue: 0
zValue: 0

Resetting values to 0
Resetting Log

Figure 2: Interactive demonstration of looping algorithms

Interactive Reusable Learning Objects for Looping Examples

This pilot study was undertaken as a means to test the efficacy and practicality of using RLO in introductory programming courses. The only component that is currently part of this pilot study is the interactive demonstration of one of the looping modules. This RLO was designed to let the students practice their code understanding abilities, as well as letting them practice the code's execution mentally before hitting the "Compile and Run" option of the IDE. The RLO is reported in Figure 2.

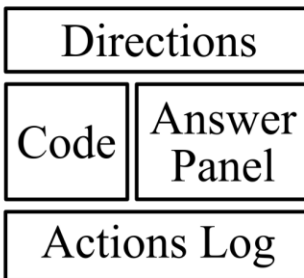


Figure 3: Structure of the reusable learning object

Figure 3 outlines the main areas that compose this RLO. In the top quadrant (Directions) students will have access to the directions on how to use the simulation as well as any information that is relevant to the example on which they are working.

The bullet to the left of each line of code can be used by the students to remember which line they last analyzed. Students can interact with the line marker through the two buttons at the bottom of this quadrant or by clicking the bullet with the mouse.

The Answer Panel features various interactive elements. Students can directly enter the values for up to three variables in the appropriate text boxes as they practice, mimicking the pen-and-paper approach to walking through the code for a loop routine. The buttons to the right of the text boxes give shortcuts for incrementing or decrementing the value of a particular variable (temporarily stored in the corresponding text box) by 1 or 10. The buttons below the text boxes allow students to check the answer by pressing "Submit answer" if they think the loop will end or "Infinite Loop" if they believe this loop will never terminate its execution. The last three buttons below the text boxes reset the simulation.

The Actions Log records the actions taken by the students. This feature allows students to back-track their actions. Through this panel the students can review their actions and either review what they did and backtrack their steps if necessary.

ORGANIZATION OF THE STUDY

Since this was a pilot study we decided not to make the material mandatory for the students but instead we allowed them to use it for reviewing purposes. The students were provided with three different sets of examples depending on the course in which they were enrolled: Java (COSC 236), Python (COSC 175), and Visual Basic (CIS 265). The instructors utilized the RLOs to trace the execution of loops during the demonstration part of a lecture. Then the students received the web address and were able to use the RLO for study and/or review purposes. The students were then given a questionnaire divided into three parts: Demographics and Miscellaneous Information, Effectiveness, and Usability. The results of the questionnaire are reported in the next section.

DISCUSSION OF THE RESULTS

This pilot study included 46 students, the vast majority (45) was composed of degree-seeking students, and 1 was a non-degree seeking student. When asked about the purpose of using this RLO, 20 students responded that they were using it to learn about loops, while 25 were accessing this resource to review or practice looping structures. One student responded that they didn't know the purpose of using the RLO. Nearly 90% of the students were using Firefox or Internet Explorer as a mean to accessing the material, while the remaining users were utilizing other web browsers. We have observed some problems with Internet Explorer, mainly due to the lack of full conformance of this platform to standards of web technologies.

Overall Reactions

We then addressed the overall reactions students had when working with this RLO. We targeted the feeling of satisfaction, how stimulated they felt, and how easy they found to interact with the tool. The results are reported in Table 1.

Table 1: Overall reactions, scale 1 (low) to 10 (high)

| Course | Satisfying | Stimulating | Easy |
|----------|------------|-------------|------|
| COSC 175 | 7.00 | 7.05 | 6.09 |
| COSC 236 | 6.50 | 5.38 | 6.63 |
| CIS 265 | 6.54 | 6.15 | 7.23 |

The students were able to rate their overall reactions on a Likert scale ranging between 1 (low) and 10 (high) on the three aspects described earlier. The overall findings suggest that students in CS0 courses find this tool satisfying and stimulating, but at the same time they were the ones who found it not as easy to use as students in other courses. CS1 students instead were not stimulated as much as students from CS0. The overall response of CIS 265 was positive, falling in the middle of the other two courses.

Perceived Effectiveness

We then asked the students information about the perceived effectiveness of this tool. These next two sections asked primarily questions that required ratings, also on a Likert scale. The results are summarized in Table 2.

Table 2: Perceived effectiveness (1: Strongly Agree; 2: Agree; 3: Neutral; 4: Disagree; 5: Strongly Disagree)

| Question | COSC 175 | COSC 236 | CIS 265 |
|---|----------|----------|---------|
| This tool was more effective in describing looping structures than the textbook. | 2.696 | 3.125 | 2.857 |
| This tool was more effective in describing looping structures than the lecture. | 3.217 | 3.556 | 3.286 |
| I would use this tool again for reviewing looping structures. | 2.696 | 2.667 | 3.000 |
| I would use tools similar to this one to learn or review other concepts of programming. | 2.739 | 2.333 | 2.357 |
| My understanding of looping structures improved. | 2.696 | 2.778 | 3.071 |
| My methodology of working through a looping structure improved. | 2.957 | 2.375 | 2.786 |

Overall we can see that the three courses still preferred a first introduction to looping through a traditional lecture or the textbook's approach. This is in line with our expectations, as we designed this RLO as an extra feature to add to traditional courses. Students in COSC 236 and CIS 265 seemed favorable to using this tool to explore other topics. Students in COSC 175 also perceive that their methodology of working through a loop has improved.

We also addressed perceived effectiveness by asking open-ended questions about their experience with this RLO. A sample of the answers is reported here:

"Lectures and exercises simply reinforce one another"

"Practice works better than reading about it"

"It was helpful for practicing but the textbook is better for learning the basics"

"The professor was more helpful, the tool just enhanced my learning"

"Actually using the tool, made me understand more than just reading the textbook"

"Lecture Explained the Loops this did a good job of showing how the loops differ from each other and how they function"

The opinions of the students seem to confirm the validity of this tool as a companion to traditional delivery of material. As this is just a pilot study, we did not explore the possibility of audio and video recording. The next step of this research will then introduce those elements to the students, creating a resource-rich environment for students to learn and review introductory programming material.

Usability

We then tested the usability of the RLO. The information was gathered asking a series of questions that asked students to rate a series of statements. Students responded using the same Likert scale range as the section on perceived effectiveness. The results are shown in Table 3.

Table 3: Usability (1: Strongly Agree; 2: Agree; 3: Neutral; 4: Disagree; 5: Strongly Disagree)

| Question | COSC 175 | COSC 236 | CIS 265 |
|---|----------|----------|---------|
| The directions for using the tool were clear. | 2.565 | 3.222 | 2.692 |
| The tool was easy to use. | 2.591 | 2.778 | 2.846 |
| The cursor was helpful in navigating through the code. | 2.545 | 2.889 | 2.769 |
| I encountered a problem while using the tool. | 3.091 | 3.667 | 2.846 |
| I was confused while using the tool. | 3.000 | 2.667 | 3.308 |
| The problems I encountered were likely related to the browser I was using. | 3.864 | 4.500 | 2.300 |
| I had difficulty reading text on the screen in the tool. | 4.182 | 4.111 | 4.231 |
| I had difficulty entering results in the tool. | 4.045 | 3.889 | 4.154 |
| The problems I encountered while using the tool impacted the effectiveness of the tool. | 3.682 | 3.600 | 2.500 |
| If I came across this tool on my own, I likely would have used it. | 3.364 | 3.333 | 3.154 |

The usability study of this pilot RLO helped us understand some key areas on which we could improve. First of all, directions were not clear enough. We need to improve directions and

integration with the environment; for example adding a tooltip help option, or additional help pages. The tool itself is not difficult to use, but we did observe that it does not fit the rich interface standards that many users have come to expect from other web based programs. Most students did not encounter problems operating the tool, except Internet Explorer users. As mentioned earlier, the lack of a consistent implementation of web standards in Internet Explorer is currently an issue. The size and positioning of the text is fine, and the usability does not seem to interfere with the perceived effectiveness. Since one of our aims is to develop fully functional objects that account for an array of learning styles, more in-depth usability studies will be needed as components are added.

CONCLUSIONS AND FUTURE WORK

Overall reactions from the pilot study have been positive. From these initial reactions, we believe that there is potential through this kind of RLO to improve introductory computing instruction, classroom demonstration and can be a useful artifact for individuals to review material. The perceived effectiveness suggests that students like this approach. This type of interactive object works well as a self paced review in addition to a more detailed explanation of the material. Video and audio explanations may help, thus the plan of the overall research seems promising. We need a tool that has a richer, more engaging interface and better directions, so that students do not have to rely on as much reading. Overall the system needs to be more intuitive. It is our goal to extend the current research to include tracking student performance within control and experimental groups and broadening the content that is available online for students.

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