TEACHING PROGRAMMING WITH ECLiP DIDACTICAL APPROACH

Agoritsa Gogoulou, Evangelia Gouli, Maria Grigoriadou
Department of Informatics and Telecommunications, University of Athens
Panepistimiopolis, Illisia, Athens GR-15784

ABSTRACT

ECLiP aims to establish a learning setting which supports students’ active involvement and contributes to the knowledge construction and the development of skills in programming through the elaboration of explorative and collaborative activities. In this work, we present the main principles of ECLiP, the three-step process for the design of activities and the design and application of three sets of ECLiP activities for the loop constructs. The results from the experimental study revealed that both the teacher and the students admitted positively the whole approach, believe that the context of the ECLiP activities can help them in understanding the function of the loop constructs and in using them in solving problems and expressed their willingness to be involved in such a didactical approach for learning various programming concepts.

KEYWORDS

Exploration, Collaboration, Programming Concepts, Learning Activities.

1. INTRODUCTION

In the context of introductory programming courses, students are expected to acquire knowledge about the main programming concepts/constructs and cultivate basic skills concerning the development of simple programs. The so-called traditional teaching approach, which is usually followed in introductory programming courses, bases the instruction mainly on (i) the sequential presentation of the generic programming concepts/constructs using a specific programming language (ACM 2001, Lidtke and Zhou 1999) and (ii) a set of activities/tasks mainly related to mathematical problems and number processing (Brusilovski et al. 1997). This approach is considered one of the main reasons for the difficulties that students encounter in introductory programming (Lidtke and Zhou 1999, Seidman 1988).

Contemporary learning theories give emphasis on students’ active involvement in teaching and learning and stress the significant value of the exploratory and collaborative learning (Vosniadou 2001). The exploratory approaches enable students to develop exploratory skills and to construct the expected knowledge while collaborative approaches give students the possibility to argumentate on their thoughts, to reflect on and refine their ideas, to feel more confident about their work and to develop collaborative skills. These approaches are considered particularly useful in subject matters, such as Informatics, that concern the understanding of the functional characteristics of various concepts/constructs and the development of skills in problem solving. Key issue of social-constructivism theories is the notion of learning activity which has to be related with students’ interests, experience and daily problems (Vygotsky 1978, von Glasersfeld 1987).

A lot of research effort is devoted to the improvement of the educational setting concerning teaching and learning in introductory programming courses. Didactical approaches are proposed and evaluated in real-classroom environments. Each one of them exploits characteristics from contemporary theories of learning such as collaborative learning (e.g. the model of “pair-programming” (Williams and Upchurch 2001)), exploratory learning (e.g. the “Black-Box” approach (Haberman and Kolikant 2001), the “Explorations” approach (Lischner, 2001)), etc. and focuses on the achievement of learning goals of a specific level (e.g. the “Black-Box” method focuses on the initial assimilation of basic programming concepts).

Towards the direction to contribute to the knowledge construction in programming, the work presented, proposes a didactical framework for the design of learning activities, referred to as ECLiP (Exploratory +
Collaborative Learning in Programming). The framework exploits characteristics from exploratory and collaborative learning and aims to support students’ active involvement and foster useful conceptual understanding and the cultivation of programming skills. In the next section, the principal foundations of the ECLiP framework are presented followed by the description of the three-step process proposed for the design of learning activities. Afterwards, the presentation focuses on an experimental study which was conducted in order to investigate a teacher’s opinion about the ECLiP framework while using it in real classroom setting and also record students’ attitude. In this context, the three sets of the ECLiP activities that were designed are presented and the results revealed are discussed.

2. **THE ECLiP FRAMEWORK**

The ECLiP framework is based on four principles that arise from contemporary theories of learning:

- The learning is realised through the construction and the suitable change of students’ structure of knowledge and cognitive model (Minsky 1985, Schank 1982). The knowledge must be incrementally constructed through the personal experience of students, the process of active participation in exploratory-oriented activities and the collaboration of students (Vosniadou 2001).

- Learning must be initiated by students. The construction of knowledge should be guided from conscious (e.g. students conceive any misunderstandings or inadequacies) or unconscious objectives (e.g. in the context of an activity, the need for the acquisition of new knowledge is emerged) that help students to be actively involved in the process of learning (Leake and Ram 1995).

- The context in which the knowledge is built and used determines its future applications (Brown et al. 1989, Schank 1982). During the construction phase of knowledge, it is considered important to relate the new acquired knowledge with situations that can be used. The connections that can be constructed for subsequent retrieval of the new knowledge structures depend on the context in which learning takes place.

- The construction and the use of knowledge should be closely related (Anderson 1983). Learning how to use knowledge must be part of the learning process; during the learning process, students should come up with various problems to see how they can use and combine different pieces of knowledge in problem solving.

Towards the direction of defining and proposing an integrated framework for the design of learning activities in introductory programming which may cover both the comprehension and the application level of learning goals, engage students actively in the learning process and promote learning through exploration and collaboration, the ECLiP didactical framework has been designed. As depicted in Figure 1, ECLiP proposes a three-step process for the design of an integrated set of learning activities (Gogoulou et al. 2003):

- **Acquiring knowledge**: Learning is more effective if students participate in learning activities that are perceived to be meaningful and the new knowledge is constructed when students require the acquisition of the knowledge (Schank et al. 1999, Vosniadou 2001, Edelson 2001). Therefore, it is important to set up conditions that (i) are likeable/meaningful to students, and/or (ii) are related to a goal that is challenging, and/or (iii) give students the opportunity to express their beliefs/opinions, and/or (iv) elicit their prior knowledge and reveal any misconceptions. Especially, in introductory programming courses, it is essential to engage students in learning activities concerning simple authentic problems that are close to their experience and show the usefulness of the programming process beyond the specific course (e.g. instead of asking students to solve numeric problems, the engagement in problems that make them to think of “mapping” an “every-day” process to a “programming” process may stimulate them to become curious and seek for new knowledge). For example, in the context of programming courses, the activities may (i) ask students to think about the correctness of alternative programs that are given as solutions to specific problems, (ii) give students a problem, an executable file (program) and ask them to run the program and try to describe the function of the program and the programming constructs that are used, and (iii) ask students to try to design the solution of a given problem individually or collaboratively.

- **Constructing knowledge through Exploration+Collaboration**: Knowledge construction is supported through observation, exploration and communication with others (Vosniadou 2001). The learning activities should guide students towards the activation and revision of their existing mental model (Ben-Ari 2001). Students’ engagement in guided learning activities and the provision of help through suitably
designed questions and additional scaffolding tasks, enable them to understand the functional characteristics of the programming constructs and revise appropriately their mental model in case of preconceived misconceptions. Moreover, students’ involvement in collaborative activities enhances learning since they have the chance to externalize/negotiate on their thoughts/ideas, to argue on their actions or on their points of view and to articulate their reasoning. For example, in this step, programming activities may ask students to (i) predict the results of given programs, to run the programs in the computer for the same input data and then to compare the predicted and the actual results and try to explain any differences, (ii) collaborate in dyads, explore alternatives solutions to a problem and comment on the given solutions, and (iii) study and test various examples and then try to modify the examples in order to satisfy specific situations.

- **Applying-Refining knowledge**: The processes of reflection and application support knowledge refinement and contribute to its retention, future retrieval and use (Vosniadou 2001). Reflection in programming may be achieved (i) by asking students to check their thinking, and/or reason their decisions, and/or (ii) by engaging students in collaborative activities in which they examine and discuss their ideas with others and/or evaluate their peers’ statements/solutions (Van Gorp and Grissom 2001, Wills et al. 1999). For example in programming, the learning activities of this step may ask students (i) to collaborate in order to discuss the solution of a problem, to design the program and then to develop the program individually, (ii) to collaborate following the “pair-programming” model (Williams and Upchurch 2001) in the design and development of a program and then to evaluate their peers’ program by interchanging their roles, (iii) to evaluate the correctness of a program and modify it according to the problem definition, and (iv) to solve a problem, then to evaluate their peers’ solution and finally to make modifications to the initial version of their solution following the comments given by their peers and justifying the changes they make.

![Figure 1. The three steps of the ECLiP framework](image)

The collaboration may take place at different stages of the learning activity, depending on the learning goal/outcomes and the underlying content. The collaboration may have the form of groups where students act (i) equivalently by discussing and exchanging ideas or (ii) according to specific roles, such as the roles of “Driver” and “Observer” in case of “pair-programming”. Although, ECLiP focuses on programming,
however the framework may be applied in any subject matter that learning may be achieved through exploratory and collaborative activities.

3. USING ECLiP IN THE CLASSROOM

The ECLiP framework was evaluated in the context of two complementary studies. The 1st study carried out in the design phase of the ECLiP framework and showed that the majority of the students of the experimental group that worked out ECLiP activities seemed to have gain deeper understanding and had better performance in the post-test than the control group that followed the traditional teaching approach (Gogoulou et al. 2003). The 2nd study, presented in the current work, focused on the investigation of a teacher’s opinion about the ECLiP framework while using it in real classroom setting for the second four-month period of the school year. In particular, the following research questions were investigated:

1st. What is teacher’s opinion about the ECLiP framework, regarding the design of activities, the application and use of the activities in real classroom and their effectiveness in learning?
2nd. What is students’ opinion regarding the ECLiP activities and the didactical approach followed?
3rd. The sets of the ECLiP activities that were designed had positive results in understanding how the “while” and the “repeat” loop constructs work and which one of them is the most suitable with respect to the problem to be solved?

The study was realized in students of Technical Educational, in the context of the “Programming” course. Twenty-two (n=22) students participated. The course is laboratory-oriented 5-hours per week. The course syllabus includes introduction to algorithms, introduction and use of the main programming constructs in solving problems, characteristics of programming environments and use of the Pascal language; the students use pseudocode and flow diagrams for representing algorithms and solutions to problems.

Before the didactical intervention, the teacher, during the lab lessons had observed that students have difficulties in defining the control condition of a “while” and a “repeat” loop in solving simple problems as well as in selecting the most suitable loop construct according to the underlying problem. In order to help students to overcome these difficulties, three ECLiP sets of activities were designed and worked out by the students: the first one was devoted to the “repeat” loop, the second one to the “while” loop and the third one to the differences between the two loop constructs. The first set was worked out by 16 students while the second and the third one by 22 students. As students had no experience in programming languages, the pseudocode was used for the representation of the programs. The whole process lasted four weeks: in the first week, the students worked out the first set of activities during a three-hours lesson; in the second and the third week, the process was repeated for the second and the third set of activities respectively; during the fourth week, the teacher discussed with the students their answers to the activities and asked them to express their opinion about the context of the activities and the whole process they participated in. Also, students’ knowledge level was evaluated in the context of the course final exams that took place after a month period time.

3.1 ECLiP Activities

The 1st set of the activities aims to help students in understanding the functional characteristics of the “repeat” loop while the 2nd set aims to help students in understanding the functional characteristics of the “while” loop. In particular, the activities aim students to be able to …

- identify the functional characteristics of the “repeat” loop (1st set) and the “while” loop (2nd set) given a pseudocode;
- specify how the “repeat” loop (1st set) and the “while” loop (2nd set) work and which are the execution results given a pseudocode and specific input values;
- determine the functional characteristics of the “repeat” loop (1st set) and the “while” loop (2nd set) in the context of solving simple problems;
- develop a program using the “repeat” loop (1st set) and the “while” loop (2nd set); and
- evaluate a solution given to a specific problem.

The context of the activities of the 1st and the 2nd set is analogous and each set includes three activities; each activity consists of a number of subactivities asking students to elaborate on and answer open or closed
questions. Initially, in the context of the first activity, the students have to think of the “programming” solution to a problem: a modified version of the “blackjack” card game (1st set of activities) and “find the number” game (2nd set of activities). The students have to design the solution guided by a set of questions such as “what variables are you going to use and for what purpose?”, “do you think that there are any actions that have to be repeated?”, “which loop construct would you use?”. In the context of the second activity, the didactical approach of “Explorations” was exploited, given the students the possibility to explore the function of the “repeat” loop (1st set) and the “while” loop (2nd set) by (i) studying relevant problems/programs, (ii) answering in questions related to the functional characteristics of the loop construct as well as the execution results of the given programs, (iii) predict the execution results of the given programs for specific input data, and (iv) executing in the computer the corresponding programs. When students finish the whole activity and observe the predicted and the real execution results, they have the possibility to rethink their answers and revise them. In the first and the second activity, the students work in dyads; in the context of the study, the formation of groups was based on the students’ knowledge level. During the third activity, the students work individually and develop the solution to the problem given in the context of the first activity; afterwards, they evaluate their peer’s solution.

The 3rd set of the activities aims students to be able to …
- distinguish and determine the differences of the two loop constructs (i.e. “repeat” and “while”);
- explain when the use of each loop construct is considered suitable and give examples of problems that demonstrate the suitability of each one of the two loop constructs; and
- select the most suitable loop construct with respect to the underlying problem.

Table 1, gives a succinct outline of the activities of the 3rd set.

Table 1. The context of the 3rd ECLiP set of activities focusing on the differences of the “repeat” and the “while” loop construct

<table>
<thead>
<tr>
<th>Expected Learning Outcomes</th>
<th>Activity context</th>
<th>Didactical approaches used</th>
</tr>
</thead>
<tbody>
<tr>
<td>The students are able to…</td>
<td>The 1st activity concerns the evaluation of given solutions in terms of the suitability of the used loop construct. In the context of the activity, students study…</td>
<td>Collaboration in dyads where the students act equivalently</td>
</tr>
<tr>
<td>• think about the suitability of the two loop constructs in solving a given problem</td>
<td>• the problem given in the context of the 1st set (i.e. a modified version of the “blackjack” card game) and a solution which uses the “while” loop although the “repeat” loop is considered more suitable,</td>
<td></td>
</tr>
<tr>
<td>• evaluate a given solution</td>
<td>• the problem given in the context of the 2nd set (i.e. “find the number” game) and a solution which uses the “repeat” loop although the “while” loop is considered more suitable, and</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• evaluate the given solution, justifying their answers.</td>
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</tbody>
</table>

Table 1. The context of the 3rd ECLiP set of activities focusing on the differences of the “repeat” and the “while” loop construct
3.2 Experimental Results

The results regarding the research questions of the study, were drawn from (i) students’ answers to the three sets of activities as well as their performance in the course final exams, (ii) students’ opinion about the activities they worked out and the whole approach followed, and (iii) the teacher’s opinion for the design and the application of the three sets of activities in real classroom.

What is teacher’s opinion about the ECLiP framework, regarding the design of the activities, the application and use of the activities in real classroom and their effectiveness in learning?

Regarding the 1st research question, the teacher has a very positive view for the ECLiP framework. She mentioned that the context of the activities stimulated students and contributed in the learning outcomes. Although, she found the design of the activities time-consuming and laborious and the application of the activities time-consuming too, she stressed that she is going to use the framework in the teaching of additional programming concepts. It is worthwhile mentioning, that the teacher considers of great importance the provision of indicative sets of ECLiP activities as teachers are not used to design such kind of activities.

What is students’ opinion regarding the ECLiP activities and the didactical approach followed?

The whole didactical approach and the context of the activities were admitted positively by the twenty-two students participated, but it was characterized as time-consuming and tedious. The students believe that the context of the three sets of the activities stimulated their interest to participate in the learning process and to understand and be able to apply the two loop constructs in solving problems. Indicative students’ comments are “it is more interesting to try to solve game-problems than the usual arithmetic problems”, “the questions are too much but if you try to answer them, you have gradually solved the problem”, “all the time you have to do something – it was hard”, “the questions helped me in writing the program”, “the bugs were more easily identified in my peer’s solution”, “evaluating my peer’s program, helped me to find out what I really know and what I don’t know”, “the collaboration results into less errors”, “when I collaborate with my peers, I can argumentate on my work”, “It was unusual. It was very interesting that we did a lot of thinks; studying programs, running programs, collaborating …”, “I liked the activities. Are you going to use such activities in your teaching process?” (i.e. the last question was addressed to the teacher).

The sets of the ECLiP activities that were designed had positive results in understanding how the “while” and the “repeat” loop constructs work and which one of them is the most suitable with respect to the problem to be solved.

The students’ answers in the three sets of the activities were quantitatively and qualitatively analyzed. Table 2 presents results according to the learning goals of the threes sets. The aim of the qualitative analysis was to investigate (i) the difficulties that students have, (ii) any improvements in the students’ knowledge level, and (iii) how the context of the activities contributed in the achievement of the expected learning outcomes. Specifically, from the analysis of the students’ answers, the following results were revealed.
− The students have considerable difficulties in the use of the loop construct in the development of a program (the percentages of students that developed a correct pseudocode were 14% and 30% in the 1st and the 2nd set respectively); while they seem to have better performance in specifying the functional characteristics of the loop construct (the percentages of the students that answered correctly in relative questions were 46% and 49% in the 1st and 2nd set respectively). From the students’ answers in the 3rd activity of the 1st and the 2nd set (i.e. developing the solution in pseudocode), it becomes apparent that although a number of students are able to express the control condition in natural language, they have difficulties in making the right formulation in pseudocode.

− The students exhibit progressive improvement when working out the three sets of activities. In particular, regarding the 1st and the 2nd set, that have analogous learning outcomes, the number of students that gave correct answer to the activities of the 2nd set was greater in comparison to the 1st set (Table 2). Regarding the 3rd set, a satisfactory number of students (75%) understood the differences between the two loop constructs; although 40% of the students gave a complete correct solution, an additional percentage of 37% students approached the solution correctly having problems in determining the initial and the update statement. Also, the students that participated in the study, following the ECLiP didactical approach, had better performance in the course final exams in comparison to their performance in the exams of the first fourth-period of the school year and in comparison to the thirteen students that didn’t participate in study (the thirteen students were not participated in all phases of the didactical approach, therefore they were not considered in the sample of the study).

− The context of the activities activated students and helped them in understanding the differences of the two loop constructs. The context of the given problems stimulated students while the exploitation of various didactical approaches (i.e. “Black-Box”, peer assessment, collaboration, etc) gave them the possibility to explore on their own the functional characteristics of the two loop constructs, to execute programs and to reflect on their solutions and answers. For example, the students while working out the 1st and the 2nd set, after completing the second activity of the set, proceeded in revisions on their answers towards the correct direction.

<table>
<thead>
<tr>
<th>Expected Learning Outcomes</th>
<th>Percentage of students that gave correct answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification of the functional characteristics</td>
<td>46% 49%</td>
</tr>
<tr>
<td>Specification of the execution results</td>
<td>59% 64%</td>
</tr>
<tr>
<td>Development of a program</td>
<td>14% 30%</td>
</tr>
<tr>
<td>Evaluation of a given solution</td>
<td>18% 27%</td>
</tr>
<tr>
<td>Specifying the differences of the two loop constructs</td>
<td>75%</td>
</tr>
<tr>
<td>Choosing the most suitable loop construct</td>
<td>52%</td>
</tr>
<tr>
<td>Development of a program</td>
<td>40%</td>
</tr>
</tbody>
</table>

4. SUMMARY AND FURTHER RESEARCH

The ECLiP framework establishes a learning setting that supports teaching and learning in introductory programming courses by engaging students actively in exploratory and collaborative learning activities which may cover both the comprehension and the application level of the learning goals. ECLiP proposes a three-step process for the design of an integrated set of learning activities: Acquiring Knowledge, Constructing Knowledge through Exploration+Collaboration and Applying-Refining Knowledge. The students have positive attitude in working out ECLiP activities and the experimental results revealed the effectiveness of the designed learning activities in enhancing learning. As far as the teacher’s opinion is concerned, she
stresses her willingness in using ECLiP framework and believes that the ECLiP activities motivate students, make them to be more active and have better performance. The ECLiP framework has been modeled and developed in the e-ECLiP web-based environment and we plan to develop learning activities for various programming constructs and concepts and use the e-ECLiP environment in the daily educational practice.

REFERENCES


