Promoting Collaboration in a Project-Based E-Learning Context

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Abstract

In this paper we investigate the value of collaboration scripts for promoting metacognitive knowledge in a project-based e-learning context. In an empirical study, 82 students worked individually and in groups on a project using the e-learning environment MyProject, in which the life cycle of a project is inherent. Students followed a particular collaboration script that combines individual and collaborative activities, aiming to promote individual and socially shared reflective thinking during the planning and evaluation phases of the project. We analysed group discussions and evaluation questionnaires, and the results provide evidence about the importance of the design variables considered in the collaboration script for cultivating metacognitive knowledge, such as project phase, roles undertaken by students, degree and type of interaction, type of activities and products, and activity sequencing. (Keywords: Project-based learning, e-learning, collaboration, peer interaction, metacognitive knowledge, asynchronous discussions)

Project-based learning (PBL) is rooted in the idea that a problem or question drives learning activities toward the construction of a concrete artifact in an authentic context. In this process, students pursue solutions to open-ended problems by formulating questions for investigation; designing plans or proposals; collecting, analyzing, and integrating information; constructing explanations and models; and creating artifacts or products of their understanding (Blumenfeld, Soloway, Marx, Krajcik, Guzdial, & Palincsar, 1991). It is also essential that learners have the opportunity to control the learning process; make decisions regarding the pacing, sequencing, and content of learning; and evaluate the outcome of their efforts and their own learning strategies. Such a learning context involves both vertical learning (referring to accumulation of the subject matter knowledge) and horizontal learning (referring to generic skills, such as project management and collaboration) (Helle, Tynjala, & Olkinuora, 2006).

The inherent openness of project-based environments seems to introduce more cognitively complex tasks in the learning process, making experience, self-direction, and high-level metacognitive control necessary for learners to effectively undertake PBL (Barron, Schwartz, Vye, Moore, Petrosino, Zech, & Bransford, 1998; Jonassen, 1999; Land & Zembal-Saul, 2003). Although the strength of PBL seems to lie in giving students the opportunity and motive to work in a personally meaningful way toward a "solution," several researchers observe students' deficiencies in performing the various activities in PBL, referring to self-directed learning skills and metacognitive knowledge (Bereiter & Scardamalia, 1993; Hannafin & Land, 1997; McLoughlin & Hollingworth, 2001; Schank & Cleave, 1995; Thomas, 2000). For example, novice learners often exhibit an absence of prior knowledge, whereas inexperienced and young problem solvers lack essential metacognitive skills, such as planning and self-monitoring, as well as a repertoire of learning strategies necessary for engaging in independent learning. Thus, strengthening students' metacognitive and reflective skills is essential in such innovative learning environments to assist them in adopting the strategies and reflective processes that will enable them to define, plan, and self-monitor their thinking and learning. To this end, computer-based tools have been used to help learners organize and reflect on their work and to support them in sharing and making their thinking more explicit and "visible" (Azevedo & Hadwin, 2005; Land & Greene, 2000; Linn, 2000; Quintana, Zhang, & Krajcik, 2005; White, Shimoda, & Frederiksen, 2000).

Especially in the area of PBL, a number of contemporary Web-based learning environments have been developed recently that support learners in dealing with the open issues of a project at the individual or group level. KBS Hyperbook (Henze, Naceur, Nejdl, & Wolpers, 1999) offers individualized navigation support to the project resources based on the learners' knowledge level and/or learning goals. Several systems focus on the collaborative perspective of PBL and provide tools, such as NetPBL (Lee & Tsai, 2004), HyperNews (Häkkinen, 2002), iExpeditions (Wang, 1999), and Connection Log (Belland, 2010), that support communication and interaction. In particular, NetPBL supports PBL in a blended learning context. It supports students' interaction and idea/artefact sharing. Students are allowed to (a) carry on synchronous and asynchronous discussions for the subquestions arising from the "driving question" of the project or for several issues under investigation, and (b) upload and share their artefacts. HyperNews is a collaborative discussion environment enabling communication among students, teachers, and experts at the planning and evaluation phases of the project work. Connection Log is a Web-based system designed to scaffold middle school students' creation of evidence-based arguments during problem-based units, allowing them to work individually and in collaboration. The above environments provide communication tools that support interaction among learners or between learners and tutors, as well as scaffolds that cultivate specific skills, at specific phases of a project in a blended learning context that combines face-to-face learning with e-learning. Designing computer-based scaffolds that may provide support at the individual or group level needs to be reconsidered in a project-based e-learning context, raising questions about student needs, necessary metacognitive knowledge and skills, the way collaborative work might be orchestrated, and the design variables that should be considered.

Following this line of research, we have developed MyProject (Papanikolaou & Grigoriadou, 2009) as a Web-based adaptive learning environment that aims to support learners in progressively understanding the implicit issues of a project and accordingly organizing their work. To this end, MyProject gives learners a set of learning activities organised as a learning cycle and assists them in following their own paths through the cycle by offering adaptive guidance. The environment also provides hypermedia educational content composed of authentic cases as well as data about learners' progress and interaction. At the group level, learners publish their own ideas and solutions when working on activities or studying the content.

MyProject has been recently extended with a peer assessment functionality as an alternative authentic evaluation approach appropriate for PBL environments (Boubouka, Papanikolaou, & Grigoriadou, 2008). This functionality enables students at specific time intervals to submit their initial products, receive peer products for review, read their peers' comments, make revisions, and resubmit their final products.

As students' metacognitive and reflective skills need to be strengthened in PBL environments, and metacognitive knowledge, such as self and task knowledge, strategic knowledge, and knowledge of plans and goals, is best supported in social settings for learning (McLoughlin & Hollingworth, 2001), we further investigate in this paper the orchestration of collaboration in order to enhance metacognitive knowledge in a PBL context.To this end, we conducted an empirical study using a collaborative learning script combining individual and collaborative activities at specific phases of a project as an additional scaffold. We used MyProject in an e-learning context where all the interactions take place online and the life cycle of a project is inherent in the environment. This work combines research from the areas of PBL, metacognition, and computer-supported collaborative learning.

In sum, the paper focuses on the following questions:

- What are the design variables for a collaborative script intended to promote metacognitive knowledge?
- What types of metacognitive knowledge should be better supported at specific phases of a project?
- Which phases of a project should be better supported by peer learning?

Research Context and Aims

Critical issues in the design of a PBL environment are project selection, matching student requirements with task requirements, and the integration of support and supplementary material with the project (Helle, Tynjala, & Olkinuora, 2006). In the process of designing support for students in a PBL environment, a valuable resource is research findings about metacognition. Metacognition is used to describe people's knowledge and regulation of human cognition (Flavell, 1979). Knowledge of cognition refers to what we know about our cognition. In particular, metacognitive research emphasizes the need to balance cognitive and social competence as well as the need to create social, interactive, and reflective environments with a holistic approach to supporting metacognition (Lewis, 1998). Social interaction promotes the development of individuals' cognitive structures as individuals reconcile differences between their own ideas and the ideas of others (see O'Donnell & King, 1999, for reviews of these theories), ask questions, and explain their reasoning for solutions (O'Donnell & King, 1999; Teasley, 1999; Teasley, 1997; Webb, 1992). O'Donnell and Kelly (1994) strongly suggest that work in groups provides opportunities for the development of members' cognitive structures and cultivates positive attitudes toward the task and stronger task motivation compared to individual work. However, research on collaborative learning has demonstrated that its effectiveness depends on the richness and intensity of interactions among the group members (Dillenbourg, Baker, Blaye, & O'Malley, 1996). Two different classes of scaffolds have been distinguished to promote collaborative learning: those that provide support on a conceptual level and those related to the interaction processes (Kollar, Fischer, & Hesse, 2006). The latter category usually structures the interaction process by shaping collaboration and assigning roles and specific activities to be carried out in a particular sequencing. Such scaffolds in the area of computer-supported collaborative learning (CSCL) are known as collaboration scripts (Dillenbourg & Hong, 2008; Kollar, Fischer, & Hesse, 2006). Collaboration scripts can vary in the degree of freedom they attribute to learners to structure their collaboration.

To this end, we investigate the introduction of collaborative tasks in specific phases of a project in a way that promotes metacognitive knowledge. At specific stages of the project work, peer learning opportunities are combined with individual activities as an additional scaffold that aims to enhance sharing of individual reflective thinking with the group and consequently increase the quality of interaction.

Currently, MyProject supports learners in working independently on a project and constructing their own knowledge. It promotes peer interaction by allowing learners to publish their ideas and solutions at specific phases of a project and to comment on them. MyProject provides scaffolds on the conceptual level as well as on the process level of completing a project. Because learners often feel lost in a project-based context, MyProject supports learners in facing the challenges posed by organizing specific activities that gradually lead to the completion of the project in a "learning cycle" and provides adaptive guidance based on learners' interaction behavior to assist

Table 1: Learning Cycle Consisting of Four Stages with Available Scaffolds

Stages	Aims	Activities/Scaffolds
Introduction: An open-ended project is proposed.	Enhance learners' (a) knowledge of plans and goals as they try to understand, clarify, and define the problem(s) that the project poses, (b) metacognitive knowledge about the task demands and goals	Learners need to define their project or specific aspects that are intentionally open. Along with the open project, initial resources are also provided.
Generate Ideas: One or more "driving questions" are proposed in association with the expected learning outcomes.	Cultivate metacognitive knowledge about the person (i.e., self-knowledge, strategic knowledge), as they elaborate on specific questions that stimulate conscious thinking about the key points of the project	Learners need to submit their perspectives (initial and final) to one or more driving questions. Links to corresponding educational material are provided next to each driving question. Access is allowed to (a) learners' initial and final answers, (b) peers' contributions (after the initial submission), along with comments coming from peers.
Multiple Perspectives and Research: Educational content consisting of authentic cases is available in hypermedia form (Kolodner & Guzdial, 1999).	Enhance learners' metacognitive task knowledge and in particular that subcategory connected to the information available as students explore the hypermedia structure of the content and study and evaluate resources while trying to understand the type and quality of available information (Flavel, 1979).	Opportunities for self-assessment are embedded in the content. Peers' contributions to self-assessment tasks as well as the teacher's proposal are available. Graphical annotation augments the hypermedia structure of the content, reflecting the type of content and learners' progress.
Solution and Evaluation: Peer assessment approach	Enhance learners' metacognitive self, task, and strategic knowledge as they need to assess and revise their own and peers' work.	A peer review activity encourages learners to submit a solution, then evaluate peers' solutions, provide review comments, revise their work based on the reviews they receive, and make a final submission.

them in moving through the cycle (Papanikolaou & Grigoriadou, 2009). The design of the learning cycle is inspired by the work of Schwartz, Lin, Brophy, and Bransford (1999) on STAR.LEGACY, which provides a visual representation of a generic process that reflects the circular nature of understanding and the interaction of action, reflection, and revision within the learning process.

In MyProject, the learning cycle consists of the stages presented in Table 1, with each stage involving learning activities that cultivate different types of metacognitive knowledge. Various scaffolds are provided at each stage to help students progressively develop knowledge and skills and become able to complete the project.

Although the learning cycle proposes a specific sequencing of learning activities, this sequence is indicatory because learners are allowed to freely navigate through the stages of the cycle. Figure 1 illustrates two screenshots of MyProject. On the top is a screenshot from the Generate Ideas stage, in which learners are encouraged to submit, in the corresponding text boxes, their initial and final responses to the driving questions. On the bottom is a screenshot from the Multiple Perspectives and Research stage, in which learners are encouraged to answer assessment questions included in the

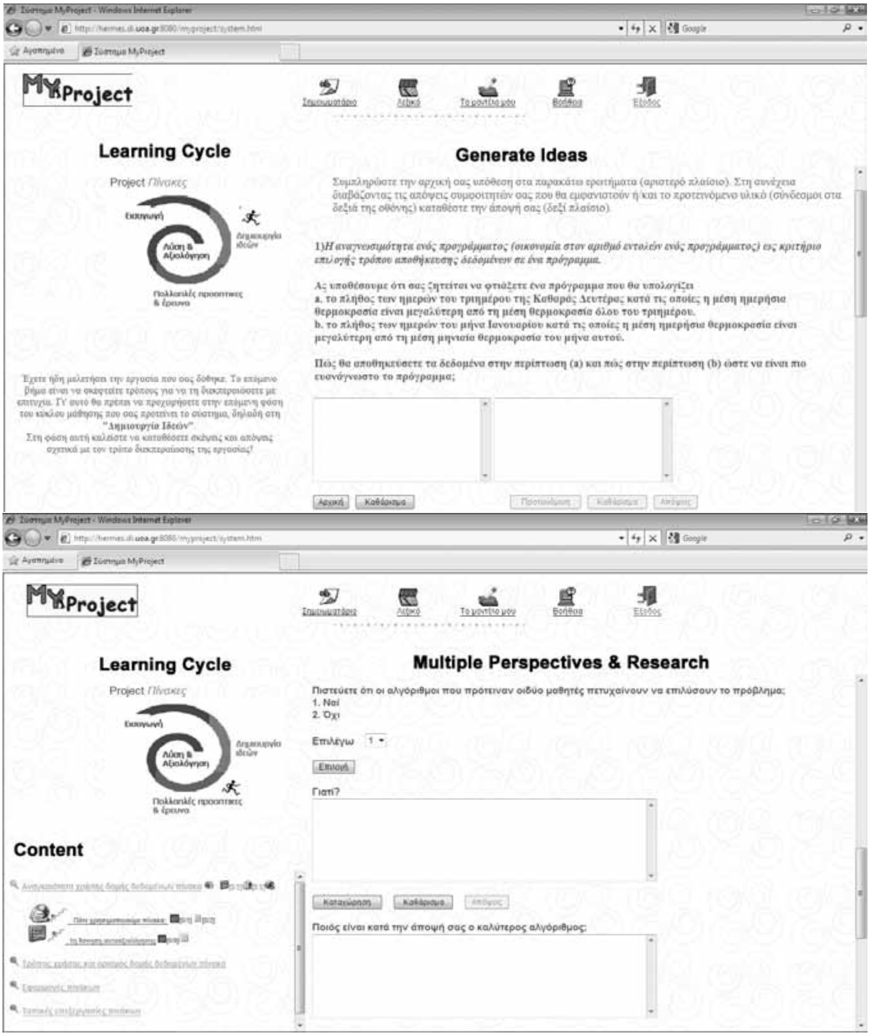


Figure 1. Screenshots of MyProject at the Generate Ideas stage (top) and at the Multiple Perspectives and Research stage (bottom).

content and submit their answers in the corresponding text box. In both cases, after students submit their initial proposals, they are allowed to access their peers' contributions. The graphic representation of the learning cycle appears on the left of both screenshots as a spiral whose parts represent the various stages, with a tiny man accompanying the current stage. Learners may visit a particular stage by clicking on the corresponding part of the spiral.

Method

This empirical study adopted a collaboration script for the planning and evaluation phases, as these are the most critical for the project work. In the particular script, individual activities precede the collaborative ones to promote sharing of individual reflective thinking during the collaborative activities. Design variables that we considered in this study are the roles that students undertake, the type of activities they perform, the type of interaction promoted at particular stages of the learning cycle, and activity sequencing. The study also explores how the following types of metacognitive knowledge, which are considered necessary for accomplishing a project, develop through the planning and evaluation phases (White, 1999): (a) self-knowledge, which entails individuals' capacity to recognise their strengths/weaknesses and evaluate themselves; (b) knowledge of plans and goals, referring to learner's capacity to set and maintain goals and to record what they intend to do through their learning; (c) task-knowledge, which involves understanding the demands of tasks and what they require; and (d) strategic knowledge, which refers to the knowledge of usefulness of strategies available for achieving learning goals.

Eighty-two (82) students attending a course titled Computer Science Education during the spring semester of the academic year 2007–2008 in the Computer Science and Telecommunications Department at the University of Athens participated in this study. The authors worked on the design, implementation, and evaluation of the study, and a third researcher was involved at the implementation phase supervising the forums as well as at the data collection and analysis phases. The whole study lasted about one month. Initially students were randomly assigned to groups, but many of them opposed this approach. Most of these students doubt the effectiveness of a randomly formulated group and insist on working with fellow students they had worked with in the past. So we decided to allow these students to choose their group. Thus, most students were organised in groups randomly (42 students; 51%), while 24 students (29%) chose their group, and 16 students (20%) experienced both situations due to several dropouts during the study.

Students worked on a project about computer programming using the learning environment of MyProject, and group discussions took place in the forum of the course's e-class environment. The particular project was part of the course, and students' performance on the project counted as 20% of their final course grades. We informed students about the collaboration script they had to follow through text-based descriptions and instructions. The time schedule was quite strict in order to make the work focus on particular topics at specific time intervals and promote participation in the flexible environment of an asynchronous forum.

Students worked individually and in groups, undertaking multiple roles with increasing complexity through the various stages of the learning cycle. Table 2 (p. 142) presents the collaboration script, which is structured in two parts that correspond to the planning and evaluation phases of a project. Each part presents the activities that students performed along with the corresponding stage of the learning cycle, the level of the activity (individual, group, or class), and the duration. Following the particular script, students initially work as learners undertaking a project about computer

Table 2: Collaboration Script for Project-Based Learning

Stage	Level	Activity	Duration
First Part: Planning Phase			
Introduction	Individual	Each student is informed about the project and explores initial resources.	5 days
Generate Ideas	Individual	Students answer the main driving questions of the project that represent the expected learning outcomes, study corresponding educational content (if necessary), and read their peers' contributions.	
Multiple Perspectives & Research	Individual	Students study the hypermedia content provided to deal with the different issues/concepts involved in the project	
	Group	Students work in groups to discuss at the forum of the e-class the open issues of the project and agree on specific goals to attain (project definition)	2 days
Second Part: Evaluation Phase			
Solution & Evaluation	Individual	Students submit their own solutions along with the definition of the project determined by the group	3 days
	Group	Students work in groups to establish assessment criteria for the final project product	3 days
	Individual	Students review the solutions proposed by the rest of the members of their group based on the commonly agreed-upon assessment criteria	6 days
	Group	Students work in groups to develop a common solution to the project	
	Individual	Students revise their own solutions to the project based on the review comments they received from peers	

programming, and then as experts/reviewers proposing assessment criteria and reviewing peer products. The script allows several degrees of interaction to encourage peer learning, including collaborative activities, sharing, and commenting on peers' proposals submitted in a shared database at the Generate Ideas and Multiple Perspectives and Research stages.

The script design takes into account the results of a pilot study of a formative evaluation of MyProject during the spring semester 2006–2007 (Boubouka, Papanikolaou, & Grigoriadou, 2008). In this pilot study, 40 subjects worked individually on a project using a discussion forum as a helpdesk at the class level. After analysing the messages posted to this forum, we found that participation was very limited. Out of 59 total posts, 29 (about 50%) referred to the project work and the remaining 30 referred to technical issues about MyProject. These findings provided evidence about the need to orchestrate collaboration to increase interaction.

In this particular script, individual activities precede collaborative activities in the planning phase of the project to allow students to become informed about the open issues of the project and study so that they could acquire a common background before going to a collaborative session, where they should decide on the main goals of their project. These activities aim to promote students' (a) self-knowledge, as they need to assess what they already know and what aspects they need to learn more about to deal with the project, and (b) knowledge of plans and goals as well as task knowledge, as the driving questions inform them about the learning goals of the project and they start thinking and discussing how they would face them.

At the evaluation phase of the project, students perform a peer assessment activity structured in several substages, in which a combination of individual and collaborative activities is proposed. Students submit their own solutions to the project as individual products and then act as reviewers/experts, discussing assessment criteria (collaborative activity) and reviewing peer products (individual activity). Students then participate in a collaborative activity in which they reflect on the different approaches they observed and clarify advantages/disadvantages by discussing with those who propose the alternative approaches. During this process, students reconsider their own solutions and collaboratively develop the "best" common solution. These activities aim to promote students'(a) self-knowledge, as they need to explain and argue for the strategies they use and comment on their peers' ideas, arguments, and strategies; and (b) strategic knowledge, as they define and use specific criteria for reviewing project products, reflect on different approaches, and evaluate alternative strategies to build a common project product.

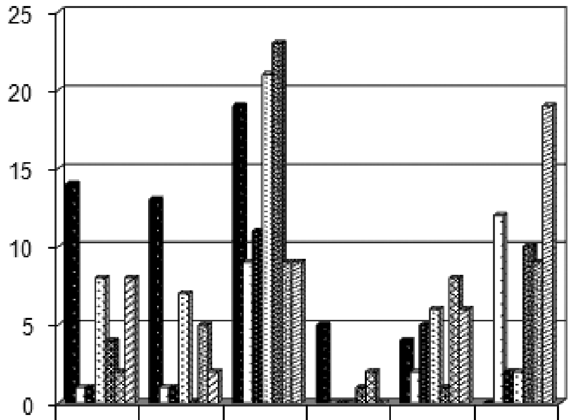
At the end of the script, students reflected on their learning experiences and individually completed an evaluation questionnaire. The study finished with a final meeting, in which students and researchers discussed the learning experience at the class level, focusing on advantages and possible improvements.

Data Collection and Analysis

The data we collected from the study and analysed included group discussions consisting of the messages that students posted at the e-class forum through the collaborative tasks, individual and group products/solutions, and the learners' evaluation questionnaires. This paper focuses on the analysis of group discussions and the evaluation questionnaires that reflect students' views.

In particular, we performed quantitative and qualitative analyses of the messages posted at the asynchronous forum to explore the type of group discussions students performed and the metacognitive knowledge they developed through the discussions. Analysis of the group discussions was based on the interaction analysis model of Gunawardena, Lowe, and Anderson (1997), which examines the social construction of knowledge in computer conferencing. In particular, it is based on the grounded theory and uses the phases of a discussion to determine the amount of knowledge constructed:

- ***Phase I:*** Sharing and comparison of information including (a) statements of observation or opinion, and (b) statements of agreement, examples, clarifications, and identifications of problems (C1 category)
- ***Phase II:*** Discovery and exploration of dissonance or inconsistency among ideas, concepts, or statements, including identification of areas of disagreement and questions/answers to clarify the source and extent of disagreement (C2 category)



	C1	C2	C3	C4	C5	other
Group1	14	13	19	5	4	0
Group2	1	1	9	0	2	12
Group3	1	1	11	0	5	2
Group4	8	7	21	0	6	2
Group5	4	0	23	1	1	10
Group6	2	5	9	2	8	9
Group7	8	2	9	0	6	19

Figure 2. Types of messages exchanged between the members of seven groups for the definition of the project.

- ***Phase III:*** Negotiation of meaning/co-construction of knowledge, including negotiation or clarification of the meaning of terms, identifications of areas of agreement, and negotiation of the relative weight to be assigned to types of argument (C3 category)
- ***Phase IV:*** Testing and modification of proposed synthesis or co-construction, including testing the proposed synthesis against "received fact" and testing against existing cognitive schema, experiences, and literature (C4 category)
- ***Phase V:*** Statements of agreement/application of newly constructed meaning, including summarization of agreement and applications of new knowledge and metacognitive statements revealing new knowledge construction (C5 category)

We categorised each message posted at the forum according to the above scheme, which we extend with a C6 category to include messages about procedural issues concerning the tasks involved or requests about deadlines, technical issues, and social issues concerning interpersonal communication and organisation of group work.

Lastly, we analysed students' answers to the evaluation questionnaire in order to explore students' attitudes about (a) the type of tasks they performed through the various stages of the project (i.e., individual or collaborative tasks) and (b) the usefulness of the peer learning opportunities provided.

The questionnaire consisted of Likert scale questions (a sample of questions appears in Appendix, pp. 154–155, where each row presents a question and each column shows the percentage of students who gave the specific answer). The questionnaire also included open-ended questions to encourage students to argue for their selections.

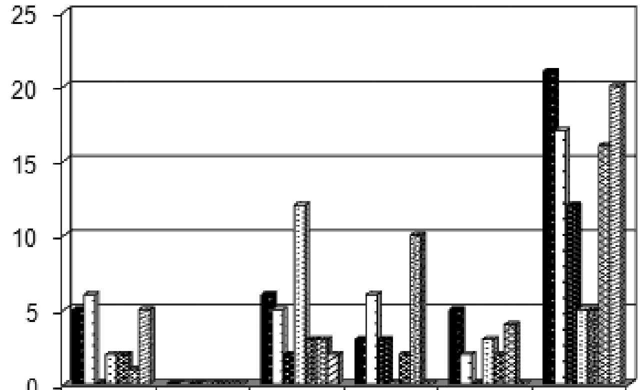
We based the questionnaire's construction on the student interviews conducted the previous academic year for the pilot study. We used students' comments about the way they worked through the various stages of the cycle to formulate the questions included in this questionnaire.

Results

Students collaborated in groups at specific stages of the learning cycle through an asynchronous discussion forum with 2,255 total messages. Below we evaluate the discussions the members of each group had about (a) the project definition, (b) assessment criteria for students' projects, and (c) development of a group product.

At the first part of the script (Planning phase), after students had worked individually to answer the initial driving questions of the Generation Ideas stage and had studied the content provided at the Multiple Perspectives and Research stage, they finally discuss in groups the open issues of the project in order to agree on specific goals and collaboratively define the project. The messages posted at the asynchronous forum provide evidence about the value of collaboration at this stage in promoting knowledge of plans and goals.

In the discussion about the project definition, 29 groups participated and 867 messages were posted. Although the type and amount of communication differs from group to group, the discussion developed to a much larger extent than was initially expected. In particular, the 29 groups discussed issues concerning the definition of their project as well as an outline of their project and the goals they would try to attain, whereas 25 groups went beyond that and discussed about how to solve the problem(s) posed, proposing and discussing alternative strategies and work plans and providing relevant resources to strengthen their arguments. The type of discussions they developed were in the C1, C3, and C5 categories, providing evidence about students' participation and elaboration on the goals of their project as well as the evolution of the group work to a final subproduct, the project definition (see Figure 2 for a sample of groups that exchanged a total of 262 messages; see Figures 2–4 for an illustration of the data from these groups). We also observed C2 discussions reflecting disagreements in several groups. Disagreements initiated a



	C1	C2	C3	C4	C5	other
Group1	5	0	6	3	5	21
Group2	6	0	5	6	2	17
Group3	0	0	2	3	0	12
Group4	2	0	12	0	3	5
Group5	2	0	3	2	2	5
Group6	1	0	3	10	4	16
Group7	5	0	2	0	0	20

Figure 3. Types of messages exchanged between the members of seven groups for the definition of assessment criteria.

new round of negotiation, usually resulting in group agreement. Discussions in the C4 category were also slightly developed. Testing was likely not a target of the discussion due to the nature of the particular activity. In sum, most of the discussions were on negotiations that included thinking aloud about alternative solutions and clarification of issues arising in the interest of reaching a consensus. This elaboration was obviously enhanced by their previous experience working individually at the Generate Ideas and Multiple Perspectives and Research stages as well as by the knowledge they acquired, as students in many cases reflect on the driving questions to strengthen their arguments about specific issues that need to be clarified in the project definition. Task knowledge also seemed to be promoted through this combination of individual and group activities, as in the process of defining the project, students decide on specific goals they would try to attain and they start thinking and discussing how this might happen.

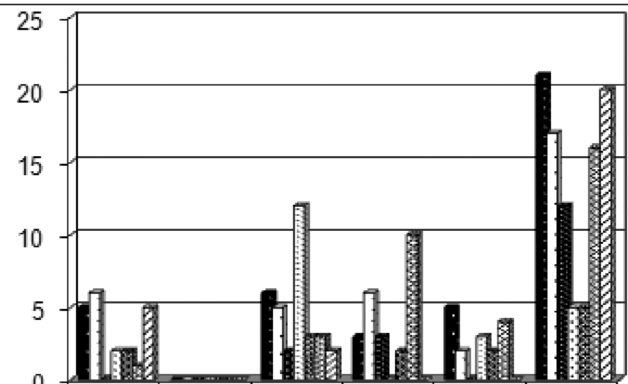
At the second part of the script and especially at the Solution and Evaluation stage, the messages posted provide evidence about the value of collaboration in promoting self and strategic knowledge. In particular, at this stage 26 of the 29 groups participated, as members of the other three groups dropped out.

Initially, the 26 groups worked to define assessment criteria for the final project product. Students proposed criteria for assessing the subject matter knowledge as well as programming and problem-solving skills. It was interesting how

the discussions evolved, due to subsequent contributions, from criteria focusing on specific programming structures to the quality of the algorithm, readability, and usability issues. They also discussed the assessment framework, including grading procedures and the type of assessment that should be adopted, as well as the value of quantitative versus qualitative assessment. Students seem to doubt the effectiveness of any grading procedure compared to qualitative assessment and feedback. The total number of messages posted was 616.
In this activity, students developed C1, C2, C3, and C5 types of discussion, providing evidence about their engagement in the evaluation process (see the sample of seven groups in Figure 3). Students also developed C4 discussions, as in many cases students suggest assessment criteria and test their validity by using them in hypothetical cases or in assessing their products. This seems to promote self-evaluation, as in many cases students apply the criteria they propose to their own solutions and share this information with the rest of the members of their group, which enhances their self-knowledge.

Twenty-two of the 26 groups then held discussions to synthesize a common solution to the project. At this substage, students discussed alternative solutions to develop a common product and at the same time revise the individual solutions they initially submitted. In this process, they discussed and compared alternative strategies to try to identify the "best" approach. This process was enhanced by the previous individual work, as the students, through the discussion, reflected on their own products and provided arguments based on their previous experience of reviewing peer solutions. The total number of messages exchanged decreased to 453; the participation of seven groups in this discussion is illustrated in Figure 4 (p. 148).

The collaboration patterns adopted for this final submission are quite interesting: 22 of the 26 groups worked on the best solution among those proposed by the members of their groups and made refinements (to a smaller or larger extent) based on the peer reviews they had already developed or received for their own solutions as well as the discussion among the group members to clarify the advantages and problems of alternative approaches. Only two groups did not manage to come to a consensus about the group product, and each member of those groups submitted a revised version of his/her initial submission. Two other groups decided to synthesize the best ideas of their members' individual solutions and submit a common final product. In many cases, students test their solutions or alternative ones provided by peers in authentic programming environments in order to synthesize the "best" solution out of the individual products, which led to C4 discussions. Students also try to revise their own solutions based on the feedback comments they received and ideas from their peers' approaches. They usually discussed strategies and clarify several issues in order to use them in their own products or the common one. This process cultivated their strategic knowledge. Even in the cases in which students adopted one of the solutions, it is quite interesting that they also tried to integrate



	C1	C2	C3	C4	C5	other
Group1	5	0	6	3	5	21
Group2	6	0	5	6	2	17
Group3	0	0	2	3	0	12
Group4	2	0	12	0	3	5
Group5	2	0	3	2	2	5
Group6	1	0	3	10	4	16
Group7	5	0	2	0	0	20

Figure 4. Types of messages exchanged between the members of seven groups for synthesizing a common product.

ideas from the rest of the individual products. In this process, they reached conflicts or knowledge deficiencies that they tried to clarify and overcome, leading to a small C2 discussion reflecting disagreements.

In sum, students constructed the "best" solution in most cases gradually as they suggested and tested various approaches until submitting the final product. This socially shared reflective thinking about alternative solutions promotes self-knowledge as students try to understand, evaluate, and integrate them into their own products or a final group product.

At the end of the script, learners completed an evaluation questionnaire assessing their learning experience through the various stages of the scenario (see Appendix, pp. 154–155). Eighty-three students completed the questionnaire. Students' answers and comments provide evidence about the value of the mode of work proposed (a combination of individual and collaborative tasks) to support them in completing the project. Specifically, most students agree (and strongly agree) that group collaboration through the forum was quite supportive for defining the project and planning their work (see Q1: 27%+57%), whereas only 6% of the students seem to have faced difficulties in this group process (see Q2: 2%+4%). Regarding students' responses to an open-ended question about their preferable way of working at the Introduction stage, 70% prefer the group work, whereas 15.5% would prefer alternative ways of collaboration, such as face-to-face communication or chat, teacher participation in the discussion, or collaboration among groups. It is remarkable that only two students (2%) were against collaboration, preferring the teacher to provide a clear project definition.

Concerning students' attitudes about the peer learning opportunities provided at the Generate Ideas stage, most of them agree (and strongly agree) that the option of submitting their proposal to a database accessible by peers was very helpful (see Q3:52%+37%). In particular, students commented that publishing their proposals in a database stimulates them to clearly explain their ideas and promotes reflection and critical thinking. Moreover, students also believe that reading the ideas of others as well as commenting on them stimulates consideration of how the ideas of others work and is quite helpful (Q4: 42%+43%). According to the students' comments, 75% of them took advantage of the possibility of sharing their ideas with peers at the Generate Ideas stage by looking at their peers' answers, and 43% commented on them. As far as the mode of work at the Generate Ideas stage is concerned, students' preferences are divided: 53% seem to prefer collaborative work for the final submission to the driving questions, whereas 47% prefer individual work at this stage (as they worked through the study) (see Q5).

As far as the Multiple Perspectives and Research stage is concerned, most students seem to easily find their own way through the educational content. At this stage, 62% of the students prefer individual work when studying the content. However, most of them seem to appreciate the option of sharing their answers to assessment tasks (see G6, Q7), and 51% of the students suggest that group work would be helpful for completing the assessment tasks (see Q8: 22%+29%). A majority (67%) of students took advantage of the possibility of sharing their solutions to assessment tasks at the Multiple Perspectives and Research stage by looking at their peers' answers, but only 24% provided comments.

Students' attitudes about the mode of work adopted at the Solution and Evaluation stage (i.e., the particular combination of individual and collaborative tasks) are positive, although various other proposals were also submitted. Seventy-nine percent of the students found that working individually to construct an initial solution was quite supportive for the learning process, while 9% of the students disagree (see Q9). Students found collaboration for the definition of assessment criteria helpful for the assessment process and for improving their own solutions (see Q10: 33%+56%). Most students reported that their group easily managed to synthesize a common product (see Q11: 36%+48%). In this process, as illustrated in Table 3 (p. 150), they also appreciate as valuable and supportive the different options of peer support, including (a) group collaboration for defining assessment criteria (89%), (b) evaluating their peer's solutions (88%), (c) receiving feedback comments on their work from peers (85%), and (d) group collaboration for the submission of a final group product (85%). Only 6% of the students seemed to find no value in these processes.

Table 3: Students' Attitudes about the Effectiveness of Various Types of Peer Support

	Positive	Neutral	Negative
Group work for assessment criteria	73 (89%)	5 (6%)	4 (5%)
Evaluating peers' solutions	72 (88%)	6 (7%)	5 (6%)
Receiving/reviewing comments from peers	70 (85%)	6 (7%)	5 (6%)
Group work for final group product	70 (85%)	6 (7%)	5 (6%)

As far as the mode of work at this stage is concerned, students suggested alternative approaches. Forty-nine students (60%) prefer working the way they were asked to (i.e., individually at first and then in groups for the construction of a final group product), whereas only two students (2.5%) prefer to work in groups at first and then individually. Ten (12%) students would prefer to work in groups throughout the Solution and Evaluation stage instead of the final part of the stage when submitting a group product, whereas ten students (12%) argue that the final product should be individually constructed based on the revised version of their initial product. Furthermore, four students (5%) would prefer teacher guidance instead of peer interaction. It is remarkable that most of the students prefer to collaborate at this stage, and none of them prefers to work individually.

Generally, students seemed to appreciate the value of interaction and collaboration opportunities at various stages of the MyProject learning cycle to complete the project. Among the benefits of collaboration, students acknowledge that collaboration (a) promoted the exchange of many different ideas and opinions (35 students, 43%), (b) supported the establishment of common goals (15 students, 18%), and (c) enhanced peer learning as they helped each other to overcome difficulties (11 students, 13%). The students attitudes about the importance of the goals they attained through the project include appreciation of (a) elaboration on the subject matter (58%), (b) collaboration (79%), (c) ICT use (59%), and (d) engagement in the project process (80%).

Other benefits that students appreciated highly were the sense of community that the collaborative tasks promoted and the immediate feedback they usually received from peers. Students also liked the combination of individual and collaborative tasks and the multiple roles they undertook. One student commented, "In a few days you pass from the role of a student to the role of a teacher." Members of groups that did not manage to productively collaborate also outlined negative attributes of group work, such as lack of communication or irresponsibility of particular members of the group.

Discussion and Future Plans

This empirical study investigated the value of collaboration in promoting the sharing of individual reflective thinking in group work and enhancing metacognitive knowledge in a project-based e-learning context. Group discussions provide evidence about the different types of metacognitive knowledge that different stages of the project work cultivated, as well as the influence of individual work on group reflective thinking and of group work on individual development. Moreover, students who participated in the study seem to value the opportunities for collaboration and peer interaction it offered, although the individual tasks were also considered necessary at specific stages of the project. They value them for promoting task motivation as well as facilitating inquiry, understanding, and application of domain concepts involved in the particular project. Below we discuss the main questions under investigation.

What Are the Design Variables for a Collaborative Script Intended to Promote Metacognitive Knowledge?

The main design variables of the script are: *project phase, roles undertaken by students, degree and type of interaction, type of activities and products*, and *activity sequencing*. In this script, students undertake multiple roles with a gradual increase of cognitive load, and the last part of the script uses a mechanism for role turntaking as they become authors, then reviewers, of peer products and finally authors of a group product. In this particular script, students were involved at the planning and evaluation phases of the project, initially in individual activities and then in collaborative ones. The degree and type of interaction among students differ at the various stages of the project (i.e., degree of interaction is considered low when students are allowed to see and comment on their peers' submissions but not to directly interact with them). Types of interaction that this script used are (a) sharing through a database accessible by peers, (b) reviewing peer products, (c) collaborating to attain a common goal, and (d) collaborating to develop a common product. The evaluation of the types of discussion performed reveal that the type of activities (individual vs. collaborative activities) that students undertake, the products that they need to construct, and the activity sequence all influenced the type of discussions they developed. For example, in the case of groups collaborating on the development of a group product, students spent considerable effort on discussing, testing, and trying out alternative approaches in authentic programming environments with the goal of synthesising a common solution. Moreover, the students' previous individual work as authors and reviewers of peer products influenced the discussions greatly. In the case of groups working to find a definition for their project, the previous individual tasks of answering the driving questions at the Generate Ideas and studying the content seem to have influenced students' proposals and contributions to the discussion. We also observed that the groups with a high communication rate (i.e., posted many messages) gradually developed discussions in the categories C2, C3, C4, and C5. However, the discussions of those groups that did not manage to collaborate was restricted to opinion sharing and practical issues. Especially at the Solution and Evaluation stage, we expected the discussions to develop much further, as students had to negotiate the establishment of quality criteria and construct a common solution. Based on the collaboration patterns that the groups adopted, only 2 of the 26 groups collaborated at the Solution and Evaluation stage in order to integrate the individual solutions to one final version. The cognitive load of this process is much heavier compared to the approach adopted by the rest of the 24 groups that decided to submit the "best" of the individual solutions with minor or major revisions.

An interesting issue to further investigate is the synthesis of the groups in terms of individual members' characteristics, such as prior knowledge, style, preferences, and how group synthesis relates to the effectiveness of collaboration or their preference for different modes of collaboration. Moreover, interaction among different groups would be another valuable parameter to further investigate as an alternative intervention for increasing the quality of interaction within a group.

What Types of Metacognitive Knowledge Should Be Better Supported at Specific Phases of a Project?

This script promotes knowledge of plans and goals as well as task knowledge at the planning phase. In this phase, after students had been informed about the underlying learning outcomes and had submitted their initial ideas on how to face the critical issues posed, the need to decide on the project's specific parameters stimulated discussion about which goals they would try to attain and how. Although students had access to educational content, their self-knowledge did not appear to increase, perhaps due to the fact that they were quite experienced programmers so they didn't "need" to study in order to define the project. Self as well as strategic knowledge increased when students had to to develop and submit their own solutions at the evaluation phase, especially when they collaborated to develop a common product and compared their own work with alternative approaches adopted by peers. Although students had individually developed solutions and reviewed peer solutions with alternative approaches, they seemed to realize the value of the strategies their peers used when they need to select the optimum solution for the final common product, and in this process they discussed the value of using theoretical evidence or providing testing results from authentic programming environments.

Which Phases of a Project Should Be Better Supported by Peer Learning?

Based on group discussions and on students' attitudes about the peer learning opportunities offered, most seem to appreciate the value of interaction and collaboration opportunities at various stages of the MyProject learning cycle for accomplishing the project. In the planning phase, including the first three stages of the learning cycle, collaboration was quite helpful for clarifying issues, defining the project, and planning their work. Alternative ways of collaboration were also proposed that involved the teacher or other groups. Most students preferred to collaboratively elaborate on the driving questions instead of simply being informed about peer ideas. They seemed to prefer studying the content on their own, although they found it helpful to share their solutions to self-assessment tasks with peers. In the evaluation phase, students found all the types of interaction involved quite helpful. Alternative modes of collaboration involving mainly collaboration/interaction among groups were also proposed.

Building on the results of this study, we intend to further investigate how alternative collaboration scripts promote the development of individuals' cognitive structures and particular types of metacognitive knowledge at each phase of the project work.

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Appendix

A sample of questions of the evaluation questionnaire provided to students.

A Likert scale is used in which 2 = strongly agree, 1 = agree, 0 = undecided, -1 = disagree, -2 = strongly disagree.

	-2	-1	0	1	2
Introduction Stage					
Q1: Do you believe that collaborating with peers for defining the project was supportive?	1%	1%	14%	27%	57%
Q2: Do you believe it was easy for your group to reach a common project definition?	2%	4%	10%	37%	47%
Generate Ideas Stage					
Q3: Do you believe that submitting your proposals to a database accessible by peers supports learning?	0%	2%	8%	52%	37%
Q4: Do you believe that the option of accessing and commenting on peers' proposals supports learning?	1%	1%	12%	42%	43%
Q5: Do you believe that submitting your answers to the driving questions at the Generate Ideas stage, initially individually and finally in collaboration with your group, would be helpful?	8%	17%	22%	16%	37%
Multiple Perspectives & Research Stage					
Q6: Do you believe that submitting your solutions to assessment tasks to a database accessible by peers supports learning?	6%	4%	8%	45%	37%
Q7: Do you believe that the option of accessing and commenting on peers' solutions supports learning?	2%	5%	10%	45%	38%
Q8: Do you believe that group work through a forum would be helpful for completing the assessment tasks?	18%	8%	23%	22%	29%
Solution & Evaluation Stage					
Q9: Do you believe that submitting individually the initial solution to the project was supportive for learning?	4%	5%	12%	13%	66%
Q10: Do you believe that collaborating with peers for defining assessment criteria was supportive for improving your solution?	2%	2%	6%	33%	56%
Q11: Did you manage to synthesize a group product easily?	7%	1%	7%	36%	48%