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Digital and Collaborative Technologies for Smarter Distance Education

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Abstract— With the integration of web 2.0 and social technologies into educational practices, researchers have been faced with the challenge of providing better online virtual learning environments, that engage students in the learning processes. This challenge entails using the massive amounts of knowledge we generate in our digital footprints to provide personalized learning contents. In our research group, we have tried to tackle this challenge by answering two questions: (i) How to share, at the same time, the knowledge of a virtual course in a decentralized way in Social Networks, MOOC, VLE and others? (ii) How to provide pedagogical practices in virtual learning environments that allow students to build their knowledge in an autonomous and reflective way? In this article we present the work we have carried out to answer both questions.

***Index Terms* — Collaborative Technologies, Distance Education, Personalization, Computational Context, Student Protagonism, Pedagogical Practices**

I. Introduction

Since the web 2.0 and social technologies were irrevocably integrated into Educational practices, many research efforts have been carried out in order to understand and optimize online virtual learning environments [1].

Implementing Distance education courses typically involves using software to support the educational activity. The use of such software leads to the creation of large repositories that record massive amounts of data about the students' learning process [2][3]. However, it is important to emphasize that simply creating large databases is useless to support courses management and students' monitoring. Therefore, supplying appropriate tools for extraction, analysis and interpretation of the information stored in these databases is essential [4].

Different from what happened a few years ago, virtual learners are now much more familiar with mobile devices and Internet resources (in their various platforms and social networks – thus characterizing what is now known as digital nomadism [5]) . Thus, they are used to work in groups.

Collaboration has been widely accepted as a way to activate relevant learning mechanisms that cannot be triggered by working alone [6]. This is partly because working in groups creates the need to articulate internal thoughts to explain a point of view, or to defend a position, and it also helps individuals to learn about others' perspectives [7].

Given this paradigm change and the growth of collaborative practices, it becomes even harder to get students of virtual courses to become interested in traditional Virtual Learning Environments (VLE), where the interfaces are not appropriate to their particular needs and collaborative tools often do not allow these students to establish relations with other colleagues, unlike what happens naturally in Social Networks and in Massive Open Online Courses (MOOC) [8].

Social Networks and MOOCs have evolved and reinvented themselves much faster than traditional VLE. The evolution of these VLE to more social ones, such as those introduced by the Ivy League MOOC generators [9] that have rapidly extended throughout universities around the world [10], is the most irrefutable fact of the integration and disruption that social and web 2.0 technologies have caused in learning and educational processes, notwithstanding the potential benefits of social collaboration among peers [11], for example.

Students do not perceive the advances in VLE at the same speed with which they sense changes in other environments, such as Social Networks [12]. MOOC are said to be a new form of online training and tend to have a decentralized, network-based, non-linear structure focused on exploration and conversation rather than emphasizing instructor-provided content.

All these issues bring another implication that needs to be taken into consideration when we use VLE: students have become much more autonomous, connected and collaborative builders of their own knowledge.

Despite the growth of Distance Education and new digital learning environments around the world, several challenges are still found in the current tools:

- From a computational perspective, we can cite the lack of interoperability/integration between systems/devices, difficulties to reuse information, unintelligent/not customized search of contents;
- . From the user experience perspective, we can cite, lack of personalized support, lack for content adaptation to different devices, lack of integration with tools they already use, among others that also contribute for the demotivation of students [8].

To proactively meet the needs of students, there is a need to consider the elements that are related to the context of the learner. Context can be understood, in this scenario, as what underlies the ability to define what is relevant at any given time.

The use of context allows the system to filter and disseminate useful information and adapt its services to the particular needs of the student, providing recommendations and changes in interfaces (to become more flexible and easier to use)[13].

Elements surrounding the learner that are of interest are: the location, the devices they use, their activities, the time of day, among others.

Thus, new approaches like context, learning analytics or educational data mining [14] should be used more often, empowering both teachers and learners in their roles. On one hand, teachers can be able to understand and optimize learning processes within their courses and on the other, students can have a better assistance and a more efficient and personalized learning [15].

Unfortunately many of the commonly used current educational technologies are not integrated; they have fixed hardware settings and typically work in isolation. As a consequence, context awareness and prediction capabilities are sparse, with limited adaptation based on the students' spatial and temporal dynamics.

To complicate matters even further, most e-learning environments centralize information, making themselves the only gateway to courses, when perhaps a more natural way would be to make information accessible in a distributed way – thus instructors could explore whichever tools the students are most comfortable with.

Many e-learning environments have been built in a similar manner over the years and continue dealing with all students in the same way, impersonally, without regard to their particular needs [16].

Considering that mobile devices and the Internet have a myriad of resources for communication and interaction, massive amounts of stored information and knowledge produced by users, together with endless possibilities for various combinations, eitherof resources, information and/or persons, we now face the challenge of allowing students to learn in distributed and context sensitive manners [8]. This is precisely what motivated the following research question in this study:

> How to provide distributed and personalized learning contents with existing digital resources (mobile devices/Internet)?

From the question that motivated this research, two other questions arose:

(i) How to share, at the same time, the knowledge of a virtual course in a decentralized way in Social Networks, MOOC, VLE and others?

(ii) How to provide pedagogical practices in virtual learning environments that allow students to build their knowledge in an autonomous and reflective way?

The concept of a "smart education" encapsulating the use of Information and Communication Technologies (ICT) for monitoring, controlling and supporting decision making in education is now widely accepted. However, most of the data found over the ICT (e.g. social networks, websites, and mobile devices) has an "unstructured" format, residing not in structured databases but in a variety of files (documents/presentations/calendars). Some research [3] [17] [18] have been developed to exploit this large amount of data and transform them into useful information for those involved in distance education courses, such as teachers, tutors, managers and students.

In this context, the overarching aim of this article is to discuss the fundamental concepts related to the challenges presented above, contemplating both the technological and pedagogical challenges. In particular, we want to support students both when they are collaborating and when they are working on their own. This article also discusses the potential generated by using social networks, intelligent agents, context and other techniques in order to promote the interaction between students and distributed virtual learning contents. In doing so, we present examples of works developed within our group that fit the two main challenges discussed above.

This article is organized as follows: Section II presents a brief literature review, discussing works related to the challenges presented; Section III presents the i-collaboration 3.0, a framework, developed as part of our work, that tries to promote the adaptation and personalization of learning contents in distributed web environments; Section IV discusses aspects of pedagogical practices that consider students' autonomy, presenting two examples of our work in the domain of teaching programming. Finally, section V presents our conclusions and open research avenues.

II. Literature Review

The concept of Web 2.0 highlights the growing popularity of 'social software' or digital social media, where users are connected to and collaborate with each other in a variety of group interactions [37]. According to [38], the Internet has become an essential mean to many new aspects of our daily lives today. Even though it may have become a commodity, the evolution of the Internet is taking new and unexpected turns [35].

Internet in education has also reached to a new context known as e-learning or web-based education process, in which large amounts of information about teaching–learning interaction are endlessly generated and ubiquitously available [34]. Development of both educational software as well as on-line web applications and databases or repositories capable of storing knowledge are indicators of the exponentially increased need of Internet and web learning systems [36].Current implementations of distance education presents some impersonal characteristics that replace the personal interaction between teacher and student in a classroom, thus distinguishing it from traditional classroom education [19]. Although different from traditional education, the interaction, dialogue and collaboration between students and professors in VLE are factors that determine the nature of learning [20], just as it happens in traditional education. These factors are closely related to the quality of participation of those involved in the process of knowledge production [4].

In the context of Technology-Enhanced Learning (TEL), system designers have tried to systematically exploit the modeling potential of computers and develop systems that support learners through adaptive or intelligent operation, to support and improve the quality of interaction and collaboration in virtual learning environments [21].

Adaptive and Intelligent systems are model-based systems that, although they have different purposes in supporting learning, aim to address the new needs of the new digital users, who are much more dynamic and nomadic. Hence, new systems should support adaptive content selection and adaptive contents presentation (interface). Thus, the learning content can be directed to better meet the needs of each student.

To meet this challenge, researchers in the field of adaptive systems try to overcome the shortcomings of traditional approaches, which deal with all users in the same way (one-size-fits-all), exploring ways in which they can adapt their behavior to the goals, tasks, interests and other characteristics of interested students [22].

In educational contexts, while the definitions of “adaptive systems” differ in the literature, many of the interpretations converge along the lines of the system's ability to adjust itself to suit individual learners' characteristics and needs. Hence, an Adaptive Educational System (AES) is a system that aims at adapting some of its key functionalities (for example, content presentation and/or navigation support) to the learner needs and preferences [22]. Thus, AES operate differently for different learners, taking into account information accumulated in the individual or group learner models.

On the other had, Intelligent Tutoring System (ITS) aim to provide learner-tailored support, similarly to what a human tutor would do. To achieve this, ITS designers apply techniques from the broader field of Artificial Intelligence (AI) and implement extensive modeling of problem-solving processes in the specific application domain.

Both AES and ITS seek primarily to meet the individual needs of each student in an intelligent (autonomous) way. The main difference between AES and ITS relates to their overall goals. While AES focus on adapting content and interfaces, ITS directly focus on supporting the learning of each student, simulating the behavior of a virtual tutor (communication). In this article, we assume that both are intelligent and autonomous systems.

During the last decade, new tools have emerged in the online learning and thus, the traditional teaching models and methods have started to change [39]. Several learning models (i.e., informal or non-formal) associated to new training methods are now present in the academic and educational sector. One of the main drivers of this transformation is the MOOC, which is an online course aimed at unlimited participation and open access via the web [39].

Despite the fact that these initiatives are very laudable, according to [43], the main problem with them is they do not guarantee effective collaboration. Just putting a group of people around a task does not imply that people will collaborate; it is necessary to encourage people to participate and collaborate. Besides that, the initiatives are still restricted to specific environments and do not provide personalized contents, which does not satisfy the aspirations of most nomadic students nowadays. To promote the adaptation and personalization of learning contents in a distributed manner in the Internet (creation of virtual learning spaces – contents available into Twitter, Facebook, Skype and GTalk, for instance), based on each student profile and needs, we present the i-collaboration 3.0 framework, detailed in section 3.

Other challenge that distance learning education brings to us is the definition of new pedagogical practices or the adaptation of old ones to match its needs. In this sense, we should be concerned about how to align the definition or adaptation of these pedagogical practices with the literature about how people learn [50]. Bransford and colleagues (2005) state that two of the key findings regarding how people learn are: (1) students should learn subjects in-depth; and (2) teaching of some subject should be integrated with the teaching of metacognitive skills.

One evidence-based practice for helping students learn subjects in-depth is through the use of self-explanations [21]. Prompting students to self-explain while they are learning was evaluated as an effective practice to foster student learning in different areas and education contexts [21, 22, 24, 51, 52].

Another way of teaching contents integrated with the teaching of metacognitive skills is through the use of self-regulation [49]. Due to challenges in VLEs, the discovery of ways to foster self-explanation and self-regulation practices in these learning environments is a new and promising path for researching.

Thus we present in section 4 two works that are being developed by our research group. The first work encourages in-depth learning of programming languages through self-explanation of video recordings [30]. The second promotes self-regulated learning of computational thinking through programing [45].

III. I-COLLABORATION

To contribute to the minimization of the challenges found in VLEs (communication difficulties, centralized access, interoperability and data integration), and thus also contribute to minimizing the various problems currently found in distance education (motivation and isolation feeling), this work presents thei-collaboration 3.0 framework. i-collaboration 3.0 is a work developed within our group that fit the first main challenge discussed in the Introduction of this article: (i) How to share, at the same time, the knowledge of a virtual course in a decentralized way in Social Networks, MOOC, VLE and others?

Despite the fact that this framework has been designed and experimented for learning domains, this project proposes innovative infrastructures fulfilling the requirements related to the nature of Context Aware and Predictive Analysis and, the Internet of Things, which are among others: heterogeneity (e.g., different objects, sensors, protocols and applications), dynamicity (e.g., arrival and departure of systems and objects), analysis (e.g., contents personalization, recommendations and prediction) and evolution (e.g., support for new protocols, systems and sensors).

The framework was designed to use intelligent agents in order to be able to collect and process data from multiple sources and to infer events or patterns that suggest more complicated circumstances (Complex Event Processing - CEP).

The proposed intelligent agent based framework deals with Distributed Problem Solving, Adaptive Personal Assistants, and Social Recommender Systems research areas, and will be better detailed in the next sub-section. The proposed framework is an extension of *i-collaboration* (1.0) model [31]. Table 1 presents the evolution from i-collaboration (v1.0) to i-collaboration 3.0.

Table 1. Proposed evolution from i-collaboration 1.0 model to i-collaboration 3.0 system

i-collaboration (1.0)	*i-collaboration 3.0*
Available only in Cleverpal VLE	Can be integrated with any VLE. It has no dependencies
An independent instance of the intelligent agent for communicating with the students in each Web 2.0 tool (Twitter, MSN and Websites).	A single instance of the intelligent agent shared for communicating with the students in all Web 2.0 tools (Twitter, MSN and Websites) and social networks
Contextual information for students (knowledge that each student has: MBTI profile, content already viewed by each student, which content each student needs to study more ...) are not integrated with Web 2.0 tools that supports the model.	The contextual information of the students are integrated between the various Web 2.0 tools, VLEs, social networks ...
The domain content is customized and distributed but is not integrated	The content domain of the system is customized, distributed and integrated
Model is not available to the scientific community	System will be available to the scientific community under a license

i-collaboration 3.0 tries to ensure distributed access to learning contents available in different Web 2.0 tools (e.g., Twitter, Skype and blogs, among others) and social networks (e.g., Facebook and LinkedIn, among others). The framework also integrates students' data to personalize the learning contents (students are distributed in the Internet – the same student can learn using Skype, Facebook and Twitter, at the same time, for example), based on the particular tastes and needs of each student (identified through de student behavior in the various Web platforms).

Given the support for virtual learning spaces, students will be able to study through the Web, using platforms and environments that they are already familiar with.

As shown in Figure 1, we assume that Twitter, MSN, a blog (Blogger site), Facebook and Moodle (VLE) are integrated with i-collaboration 3.0 framework, meaning that these environments are using i-collaboration 3.0 (there is an user account in each of these environments connected with the framework).

In the presented scenario, a single instance of an intelligent agent, which is provided by the i-collaboration 3.0 framework, is available in each of these environments (such as a contact on MSN, as a user in Twitter, and as a chatterbot in Sites and VLEs, for instance). Despite the fact that the intelligent agent appears in many different environments, the framework provides a single agent to them all. In other words, the student talks across different environments with the same intelligent agent. If a Science Computer student starts communicating with the intelligent agent in Gtalk, asking him about the 'main function' of a program: "what is a main function?" he will get an answer about the main function, as requested. A few minutes later, the student goes to the MSN and asks the same thing to the intelligent agent: "main" (because he still has doubts). At this time, the intelligent agent recognizes that this student has communicated with him through Gtalk, asking him about the same thing (and within a short time interval). The intelligent agent then reasons about the students' interactions with him, such as student question, student environment, studied contents, student exams scores, student profile and answers him with new questions: "Did we not talk about it?" "You need more help with this issue?". If the student needs more help, the intelligent agent must suggest to this student related contents based on his doubts in introduction to programming.

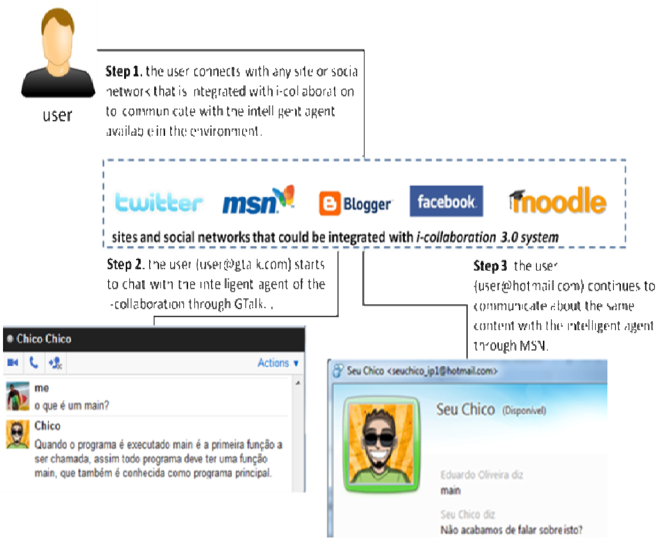

Figure 1. i-collaboration 3.0 example of use.

To try exams and to suggest other logins on other Web tools 2.0/social networks, students use special commands such as "#exam", to do an exam, and "#addEnvironment Gtalk mylogin@gmail.com" to set a new login to the student (student is in MSN adding a Gtalk login, for example – teaching the bot his others logins distributed in the Web).

These metadata are monitored through Drools inference engine (rule-based reasoning) [32]. Drools is responsible for integrating students distributed data and for considering context while students are making questions (repeated questions, in a small period of time, about the same subject, means that the student is finding difficulties and needs help, for example).

The advantage of providing a single intelligent agent in the system lies in the fact that with only one agent, we can also have a single integrated database in the framework (based on students' interaction with the agent in distributed environments). If a student interacts with the intelligent agent through Facebook, the agent will know, referring to the historical database of the student that he has already communicated with him through Twitter and MSN, and that s/he has demonstrated interest in studying programming concepts before. i-collaboration 3.0 extends the model of i-collaboration 1.0 [31] in order to make it accessible to all students of VLEs with decentralized, integrated and adaptive features. If needed, for performance reasons, more intelligent agents can be used in the framework.

A big challenge in developing virtual learning spaces that offer interoperability of distributed data on the Web, is the personalization of these distributed contents, so that each student has their needs met in the environments that they use to acquire new knowledge.

According to Vieira and colleagues [13], the quality of context-aware services is directly related to the quality of the information collected by the systems. Context can help i-collaboration 3.0 to improve how contents are provided to each student, adapting them based on the students' individual profiles, which are based their own needs (and on their favorite environments).

Student data are dynamically collected and analyzed based on their interaction with the intelligent agent of the i-collaboration 3.0. The architecture designed and developed to achieve the objectives of i-collaboration 3.0 was defined based on the following requirements:

Requirement 1 - Decentralization in access to contents of virtual courses
Web environments and social networks that make use of the framework are identified as clients of the framework. The client (Web environment or social network) to be integrated with i-collaboration 3.0 must implement an interface provided by the proposed framework. After the communication interface implementation by one or more Web environments, an instance of the framework, which relies on the intelligent agent of the i-collaboration 3.0, the context and personality tests modules (Myers-Briggs Type Indicator - MBTI [33]) will be available and integrated into the Web environment or social network, so students can use them.

Requirement 2 - Interoperability
Interoperability is the ability of a system (computerized or not) to communicate seamlessly with another system (similar or not). After having identified a way to allow interoperability between different systems and Web environments with the proposed framework, through the use of an intelligent agent common to all environments, our third challenge in the design of the framework was to ensure the data consolidation between the various student environments.

Requirement 3 - Consolidation of distributed data of students
i-collaboration 3.0 framework has been designed to work with a single intelligent agent and a single database. All Web environments and social networks should use the framework share this unique database. The database stores information such as the id of the student, Web environments and social networks they use to learn, areas of interest, exams scores, among other information. The intelligent agent manages and controls the student's data stored in the database.

Requirement 4 - Personalization and Content Adaptation
A context module was designed for the contextual information that should be considered in the framework and how such information is connected. Based on data analysis (Requirement 3), combined with MBTI [33] profiles and behaviors of students, the contextual module is responsible for personalization in the learning contents.

i-collaboration 3.0 supports the creation of virtual learning spaces and proposes innovative infrastructures related to the nature of Context Aware and the Internet of Things. Each student is treated in a unique way and uses the environment they are more comfortable with, thus motivating these students to interact and learn.

The results obtained from an experiment with 65 students in a period of 60 days suggested that the framework can contribute to greater student interest in the pursuit of knowledge. We intend to carry out more detailed experiments in the near future, as a way to ensure the quality of the results obtained so far.

The framework is also being expanded and integrated with new platforms (Gmail and Facebook). In the future, the framework will be available under a software license for the scientific community use.

IV. PEDAGOGICAL PRACTICES

Although providing appropriate infrastructure for virtual learning environments is a first step in the direction of reducing the challenges found in distance education, it is not enough. Besides that, we need also to provide pedagogical practices that allow students to build their own knowledge in an autonomous and reflective way.

Hence, this work presents in the following sub-sections two different pedagogical practices that fit the second main challenge discussed in the Introduction of this article: (ii) How to provide pedagogical practices in virtual learning environments that allow students to build their knowledge in an autonomous and reflective way?

The first pedagogical practice we present is the self-explanation of video recordings [30] which has been developed to the programming domain. The other practice proposes a collaborative model that combines self-regulated learning with the computational thinking domain [45].

A. Self-explanations

Usually, courses in distance education learning environments have a set of different kinds of instructional material in which teachers present pieces of the subject they are teaching every lecture. In the case of programming courses, video recordings have been proposed as an ideal instructional material for presenting the dynamic process of programming to novice learners [25].

However, when teachers are planning their courses, they should be concerned not only about the way they structure these video recordings, but also about the way students are guided while studying them. For this purpose, one example of pedagogical practice that is being developed in the programming domain is the self-explanations of video recordings [30], a practice we adopted in i-collaboration 3.0.

This practice builds on two different lines of research. First, in order to organize the set of video recordings produced by teachers, we are using the Stepwise Improvement [26] [27], a conceptual framework that describes programming as a systematic and incremental process that comprises the activities of extending, refining and restructuring code. These activities are organized in a three-dimensional space that is explored by programmers while they are building programs. This framework provides guidance regarding the structure of instructional material and, thus, novice learners can learn to program in small steps by extending, refining and restructuring pieces of code systematically and incrementally during their course.

The second line of research aims to provide guidance in the way students study and understand these video recordings. For that, we propose the use of self-explanation [22][23][24], a type of dialog that learners have with themselves while they are learning from different instructional materials. According to the literature, the process of self-explaining increases students' knowledge through the refinement of the given information, associating this new information with their prior knowledge and connecting it with other different pieces of information.

In this context, for each activity in the Stepwise Improvement framework, we specified intended learning outcomes (ILOs) as shown in Table 2. These ILOs guided the definition of teaching and learning activities and assessment tasks [29] for a programming course structured according to the framework.

Table 2: ILOs for activities in Stepwise Improvement.

Activity	Intended learning outcomes
Extension	**Describe** goals that should be achieved in the use case and **define** the action plan to achieve these goals.
Refinement	**Apply** the basic concepts of programming language to build a coherent program that follows the action plan previously defined.
Restructure	**Evaluate** the current code, **define** and **apply** an action plan to alter the current solution.

For each activity performed in the programming space, students have a teaching activity, that is, a video recorded by an expert to watch. After watching each video, students have a corresponding learning activity, that is, a set of questions that should be given to them. These questions, called self-explanation prompts, guide students to explain by themselves what they have just seen in each video.

In order to illustrate this approach, we have chosen to use The Joy of Code video recordings [28] as teaching activities. These videos teach Java programming language using the Greenfoot tool. They were produced according to the Stepwise Improvement framework and edited to match its activities. We present a printscreen of one of The Joy of Code video recordings in Figure 2.

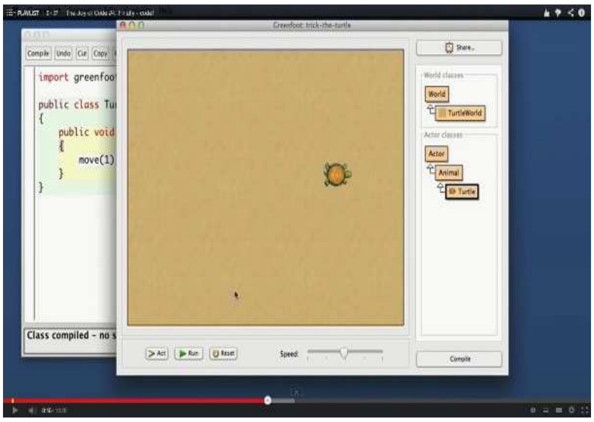

Figure 2: Printscreen of The Joy of Code video recording.

The expert that recorded the video recording presented in Figure 2 performed an extension followed by a refinement activity. Because of that, first, he described the goal he wanted to achieve with the new use case he was extending, and defined an action plan to achieve this goal.

In this case, the goal was to make the turtle move and the action plan was to write the line `move(1);` inside the `void act()` method. After that, the expert coded that plan in the program, applying the programming concepts that students had learned up to that time.

For each piece of video, we defined a corresponding set of self-explanation prompts that were aligned with the ILOs previously defined. Hence, when the students finish watching this video recording, they will be able to answer the questions presented in Table 3, which is related to these activities of extending and refining code.

Table 3: Questions related to The Joy of Code video.

Activity	Questions
Extension	What is the main goal of the piece of code that he has just written?
Refinement	How did he write code to make the turtle move? What is the purpose of the parameter (number '1') in the move method? Where did he write code to make the turtle move? When did he use the move method?

Through stepwise self-explanations, we would like to guide students in making sense out of the different pieces of content that are presented to them in different video recordings, and thus acquire knowledge . Besides, we would like to encourage them to become deeper and more reflective learners.

B. Self-regulated learning

Recent literature on the teaching of computational thinking in high school emphasizes the need to engage students in activities of reflection while they are learning computational thinking skills [47].

From the perspective of self-regulated learning [49], reflection, or more specifically self-reflection, plays an essential role in the learning process by enabling learners to evaluate their own knowledge in an attempt to identify the causes of their academic mistakes and successes. Students can perform these activities of reflection and evaluation of their own learning both individually and in collaboration with their peers.

To this end, we present penC [45], a collaborative model that introduces self-regulation practices into the domain of teaching and learning of computational thinking skills through programming.

penC is built on the notion that encouragement to students' self-reflection during problem solving triggers the development of self-regulation practices and has the potential to improve the learning of computational thinking through programming.

This model intends to create the appropriate conditions for high school students to develop skills and competencies required today, think about themselves as problem solvers and reflect on their ongoing learning experiences.

To do that, penC consists of four phases which are performed while students are solving each new programming problem.

The first phase, pre-reflection consists of two activities. In order to stimulate students' reflection on their learning process as whole, the first activity in the pre-reflection phase presents student current state with respect to the ILOs that should be achieved in an introductory programming course. The second activity aims to help the students' reflection about the problem to be solved, helping them recognize the goals and identify the data, and building on their confidence to solve it. To do that, this activity presents a set of self-assessment questions that should be answered by the student before s/he starts to solve the problem. The answers collected are used in the last phase of penC model in order to evaluate the student's level of confidence.

The second phase of the penC model is called resolution. In this phase students solve a programming problem following coding standards (e.g. naming variables). During problem solving, there are scaffolds that help learners to reflect on the current problem based on their previous experience on solving programming problems. At the end of this phase, students submit the final solution before the deadline set by the teacher, who can monitor the students with difficulties in solving the problem and provide feedback according to the needs of learners.

Peer assessment is the third phase of the penC model. In this phase, the solutions submitted by students are evaluated by their peers. At the beginning of this phase, these solutions are assigned to at least three other students who should understand the assessment criteria. This activity is important in two aspects. The first aspect is because an inaccurate understanding of the criteria may interfere with the form of assessment and, consequently impact the learning of the students who receive the comments. The other aspect is that the teacher will be notified of those student evaluators who do not understand the criteria and can follow their assessment.

The list of criteria for assessing students' solution provides a quantitative and qualitative analysis of the solution. For each assessment criterion, the assessor should provide a score and also a written feedback to assist the student to reflect on what they have done. In this sense, scaffolds were designed to assist evaluators to write reviews that demonstrate the strengths of the solution, point errors and suggest improvements. At the end of this phase, each evaluator sends back its analysis to the creator of the solution.

The fourth phase of penC is post-reflection, which aims to engage students in reflecting about solving programming problems.

At the beginning of this phase, students can see the feedback given to their solution in the previous phase. After seeing their feedback, students also assess the quality of the received feedback. Then, students may choose to share with other students their solutions and receive new reviews, a process that stimulates new discussion about the solution shared.

At the end of the post-reflection phase, students can also monitor their learning process through different activities. First, they can analyze charts which present two aspects of monitoring capabilities: the Knowledge Monitoring Accuracy (KMA) [48] and the Knowledge Monitoring Bias (KMB) [46].

The KMA refers to the student's ability to infer how s/he will perform in a learning task and, depending on the result obtained from the KMA, the KMB indicates if the learner is pessimistic, optimistic or random. Analyzing the charts presented, students can reflect and monitor their own learning process of computational thinking. In addition, s/he can interact with the charts presented and interpreting the results in a self-assessment process. Second, they may compare their results with the results of their peers. Finally, they may discuss different problem solutions shared with their peers.

V. CONCLUSION

The Web 2.0 has changed significantly the way users relate and communicate through different digital environments. With respect to technology-enhanced learning, the consequences of this state of affairs are that students are much more comfortable using their own social tools, and thus are not happy to spend time and effort using particular VLE.

Since the Internet has a myriad of resources for communication and interaction, we now have massive amounts of stored information and knowledge produced by users. Moreover, lots of new wearable and mobile devices are available and together these technologies can bring more possibilities for new educational strategies.

A new educational challenge for i-collaboration 3.0 framework is to provide better experiences for students, researchers, teaching staff and those in the surrounding communities in various aspects of their university campuses daily lives. In this light, the new i-collaboration 3.0 project aims to develop a context-aware middleware for a smart campus. As a middleware, we expect that i-collaboration 3.0 will be able to collect, integrate and analyze distributed and heterogeneous data from a large number of independent, autonomous, distinct and interacting sub-systems. These are the necessary support for extremely complex smart services and applications needed to create a Smarter Campus. To do this, it will be necessary to research alternative methodologies/frameworks/algorithms, specify and develop a context-aware middleware that integrates solutions and employs careful monitoring, accurate prediction of future behavior, and automatic maintenance of the involved network systems.

Besides the development of this new infrastructure, we should also be concerned about developing and evaluating other pedagogical practices that match VLEs' needs.

For instance, we promote a more active learning through the definition of a set of learning activities that engage students and, consequently, promote deeper learning in different types of activities, such as standalone or collaborative study.

In the programming domain, these activities can include production of different instructional materials by the students (e.g., video recordings of problem solutions and program codes, among others) and spaces where they can share those materials and also interact and receive feedback from their teachers and peers. Also, teachers can reuse instructional materials produced by other teachers and include learning activities, such as questions, which make students study more thoroughly while learning a specific content.

Given the importance of teaching metacognitive skills integrated with some subjects, we should provide new mechanisms that can promote other skills besides self-reflection and self-monitoring.

We also intend to carry out more elaborate experiments, in order to better evaluate the impact of such frameworks on learning.

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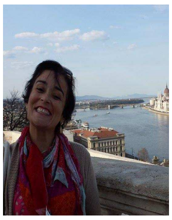

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