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A Review of Constructivist Learning Methods with Supporting Tooling in ICT Higher Education: Defining Different Types of Scaffolding

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Abstract: Information and Communication Technology (ICT) engineering education is facing a decreasing interest by students. To deal with this issue, a need for shifting from traditional learning approaches to constructivist methods has been identified. Several pedagogical methodologies based on social and constructivist theories are being applied to engage students in ICT education. This paper presents a literature review of studies carried out from 2000 to 2010 that have applied constructivist learning methods with supportive tools to specific ICT areas. From the analysis of the literature review this paper identifies the most representative constructivist learning methods within the field of ICT education. In particular, we pay attention to the educational tooling used to support the learning process and the learning benefits of applying such methods. The analysis also reveals that different combinations of guidance approaches and tooling implementations are often adopted to scaffold the learning process. With the aim of understanding to what extent and how scaffolding is present in the studied learning scenarios, this document proposes a definition of different types of scaffolding techniques. Namely: social-guidance and system-guidance scaffolding, depending on whether an individual or a tool is the responsible for providing support to students; macro-scaffolding when pedagogical methods define activity flows, or micro-scaffolding when the support is provided to perform specific actions within activities; and tool-enveloped scaffolding, when a generic tool such a learning management system scaffolds the learning process by the integration of different supportive tools, and tool-embedded scaffolding when the scaffolding is applied within a specific-purpose tooling.

Keywords: Literature Review, ICT Engineering Education, Teaching and Learning Strategies, Constructivism, Scaffolding
Categories: A.1, L.3, J.0

1 Introduction

In response to the decreasing interest towards Information and Communication Technologies (ICT), instructors, academicians, and practitioners have investigated how students should learn this subject matter [ACM, 09; Stephenson, 09]. Many studies have pointed out the changing students' characteristics in the new area, indicating a need for a shift to new pedagogical techniques. In that way, recent educational research in ICT education has been guided by social and constructivist learning theories such as Problem-based Learning or Inquiry-based Learning, which emphasize that learning is an internal and social dialogue [Hrastinski, 09]. Inspired by these studies, the field of education has recently begun to move from the use of traditional learning methods to constructivist approaches (e.g. Collaborative Learning, Problem-based Learning, Project-based learning, Cognitive Apprenticeship, Inquiry-based Learning) that encourage lifelong, collaborative, student-centred, and self-regulated learning [Baturay, 10].

Besides, in traditional learning methods students gain knowledge at the most basic level and memorize scientific facts without understanding the underlying concepts [Cepni, 06]. As a result, misconceptions about these concepts can be developed. Misconceptions can be strongly held ideas, and these ideas are difficult to change with traditional learning methods [Yenilmez, 06]. To improve students' understanding and reduce their misconceptions, researchers are beginning to examine the effect of more constructivist learning approaches [Zydney, 10]. Constructivism considers learning as an active process in which learners construct new ideas or concepts based upon their previous knowledge [Bruner, 86].

Furthermore, according to [Bourgonjon, 10] a growing number of authors believe that the new generation of students is fundamentally different from former generations, mostly because of changes in their media consumption patterns. They grow up with hypertexts, social networking programs, and videogames. These students have gained specific technical skills, new ways of thinking, and different learning preferences, requiring new educational approaches [Prensky, 01]. Technological tools (e.g. visualization approaches, interactive tools, computer games, computer simulations) in conjunction with constructivist learning approaches provide a good opportunity to engage students in ICT concepts.

On the other hand, most of the learning methods based on Constructivism are characterized by open-ended, complex, and problem-solving environments by which students must construct their knowledge. Besides, when learners are being asked to solve nontrivial problems, they often need greater support to reach accurate conclusions and desired outcomes. To this end, the instructor can provide corresponding instructional aids to learners, so as to facilitate their learning process to accomplish tasks that ordinarily cannot be performed by their own [Chan, 07]. In this context, supporting approaches or scaffolding techniques are often needed to help students succeed in their learning and to achieve the expected learning outcomes [Zydney, 10]. Scaffolding is a term coined by Wood, Bruner, & Ross [Wood, 76] elaborating on the ideas of Vygotsky's approach and the notion of the Zone of Proximal Development (ZPD) [Vygotsky, 78]. While Piaget's theory is focused on the fact thata biological drive that determines how individuals come to acquire, construct and use the knowledge; Vygotsky looks more to social interaction as the primary source of cognition and behaviour [Huitt, 03]. The ZDP is described as the distance between actual development during independent problem solving and the learner's potential development. This means that scaffolding techniques involve different type of processes (e.g.: coaching through prompts, templates and guides, tools, strategies,…) that teachers implement to support students in problem solving activities whose goals would be beyond their unassisted efforts [Wood, 76; Ge, 01]. Thus, scaffolding techniques can provide the necessary support to improve the students' learning outcomes and engage students along the learning process.

Therefore, this paper presents a literature review of studies that have successfully applied constructivist learning methods to specific ICT fields. We pay attention to what supportive educational tooling (i.e. those technological approaches that are used in learning situations) have been used to engage students in the learning process, and how scaffolding techniques have been used to provide support to students. More specifically, the questions that built the foundation for this literature review are:

1. What are the most representative constructivist learning methods within the field of ICT education?
2. What are the supportive tools for learning used in order to support those constructivist learning methods to engage students in the learning process?
3. What are the learning benefits of applying such approaches?
4. To what extent and how are scaffolding techniques present in the learning process to improve the learning performance?

The remainder of the paper is structured as follows: First, we describe the methodology used to select the papers relevant to this study. In order to answer the first three aforementioned questions, Section 3 analyses the learning methods most representative of specific ICT related-topics. Besides, we classify each method indicating both the supporting tooling and the learning benefits. To answer the forth question, Section 4 defines the different types of scaffolding techniques applied to the learning processes studied. Finally, Section 5 concludes this work and highlights future possible directions for further research.

2 Research Methodology

For the purposes of this study, we carried out a thorough search in Computers & Education, Transactions on Education, and Computer Applications in Engineering Education journals. These are representative journals that have been selected because of their relevant impact (they are indexed in the well-known ISI Web of Knowledge) in the different areas of the scope in which is framed this research: the technology enhanced learning field; the engineering education field; and the use of computer applications in engineering education. More specifically:

- To search representative papers in Transactions on Education we specified, from the IEEE Xplore advanced search options, the publication title "Transactions on Education". Then, we delimited the year range from 2000 to 2010. As a result, a total of 924 were retrieved.
- From Science Direct webpage, we searched the papers related to Computers & Education journal. To do that, we specified "Computers & Education" as a journal name within the journals tab that appears in the advanced search option. We selected "article" as a content type, and also delimited the year range from 2000 to 2010 including articles in press. A total of 1145 papers were retrieved.
- From Wiley InterScience advanced search webpage, we specified in the publication title field "Computer Applications in Engineering Education" to

retrieve the papers of this specific journal. We also checked "journal" as the product type and specified the date range from 2000 to 2010. The result of this search was 603 retrieved papers.

We read abstracts of each retrieved paper and exclude those papers that did not meet the inclusion criteria for this study:

a). Studies had to concern a learning method based on the constructivist theory (i.e. Collaborative Learning, Problem-based Learning, Project-based learning, Cognitive Apprenticeship, Inquiry-based Learning);

b). Studies had to be applied to Higher Education;

c). In order to delimit ICT topics, the studies had to be related to a certain area of computing majors (i.e., computer science, computer engineering, information systems, information technology, or software engineering);

d). Studies had to specify either general or devoted software tools used to support the specific learning methods.

After examining abstracts, the majority of the retrieved articles did not meet the aforementioned criteria. Some of them did not indicate the learning methods or the supportive tools for learning used in their experiments, other contributions focused on fields different from computing majors, and other studies were carried out in primary or secondary education. As a consequence, 23 papers met the criteria for inclusion: 16 representative papers from Transactions on Education; 4 from Computers & Education; and 3 from Computer Applications in Engineering Education. Besides, as a result of tracking the references of some of these selected papers and previous knowledge of related papers, we found additional relevant papers published in other journals and conferences. As a consequence, a total of 10 papers were selected for inclusion in this research synthesis. Table 1 shows an overview of the specific information sources and the amount of selected papers used for this literature review.

Source	**# Selected Papers**
IEEE Transactions on Education	16
Computers & Education	4
Computer Applications in Engineering Education	3
Conference on Frontiers in Education	3
Int. Conference on Advanced Learning Technologies	2
Int. Workshop on Groupware	1
Conference on Software Engineering Education and Training	1
Asia-Pacific Software Engineering Conference	1
Int. Conference on Intelligent Networking and Collaborative Systems	1
Int. Workshop on Education Technology and Training & International Workshop on Geoscience and Remote Sensing	1

Table 1: Sources and number of related papers included in this study

In order to analyse the most representative constructivist learning methods within the field of ICT education (Research question 1), we classified in next section the selected papers according to the constructivist learning methods that they have applied to specific ICT areas. Following the same reasoning, we indicate the educational supportive tooling used with these methods (Research question 2), and the learning benefits derived from applying such approaches (Research question 3).

3 Constructivist learning methods and educational tooling applied to ICT education

The constructivist learning methods described in this literature review include Collaborative Learning, Problem-based Learning, Project-based Learning, Cognitive Apprenticeship, and other less representative learning methods applied to ICT education. These methods are used in conjunction with supportive educational tools to allow students investigate their own strategies. In other words, supportive tools for learning enable students to formulate and test their hypotheses, analyse their findings, interpret and make sense of their results, and draw their own conclusions [Liang, 10]. The following subsections describe how constructivist learning methods in combination with supporting educational tooling are used to assist learning of ICT-related concepts.

3.1 Studies of Collaborative Learning in ICT education

According to [Dillenbourg, 99] “the words ‘collaborative learning’ describe a situation in which particular forms of interaction among people are expected to occur, which would trigger learning mechanisms, but there is no guarantee that the expected interactions will actually occur”. In that sense, scaffolding techniques are used to support potentially effective collaborative environments. Table 2 collects the identified research studies that used ICT-devoted supportive learning tools in collaborative learning environments to teach specific ICT concepts.

CNP (Compiler-Network-Processor) is an integrated laboratory in which students, working in groups, use specific tools such as a graphical simulator, light-emitting diodes (LEDs) on a SOPC board, or GNU g++ on Linux workstations to support the collaborative activity flow of this laboratory. An instructor and a teaching assistant are in charge of guiding the groups. The integrated laboratory and associated collaborative activities led the students to high levels of understanding [Abe, 04]. Focusing on computing networks, Conquer the Net is a two-player risk-based game to allow students learn basic configuration of networking components, and developing tactic, strategic, and negotiation skills [Arevalillo-Herráez, 09].

Studies	Tools applied to ICT Ed.	ICT or related areas	Learning benefits	Scaffolding approach
[Abe, 04]	Several specific tools	Processor organization, compiler design, and computer networking	High level of understanding	Teacher's assistance
[Arevalillo-Herráez, 09]	Computer Game ("Conquer the Net")	Networking applications	Improvements of tactic, strategic and negotiation skills	Not Available/ Unknown
[Chang, 03]	Web_Soc (Web-based tutoring system)	Recursion programming concepts	Students' performance improved	Teacher's observation + Socratic dialogue provided by Web_Soc
[Moreno, 07a; Moreno, 07b]	Moodle and SIMDE simulator	Instruction level parallelism topics	Deeper knowledge, better understanding and higher level of motivation	Teacher's mediation + Moodle integrating a Simulator
[Regueras, 09]	QUEST integrated into Moodle	Communications Networks	Higher performance	Moodle integrating QUEST
[Harrer, 06]	Remote Controller	Modelling ICT-based processes	Not Available /Unknown	The Remote Controller itself
[Grigoriadou, 06]	Web-based System including a simulation program	Computer cache memory	Enhanced learning	The integration of different tooling in the web-based System
[Chenard, 08]	Teaching Platform	Wireless Embedded Systems	Students more interested, a more rapid ramp-up in students embedded programming skills	The teaching platform itself + teacher's demonstrations
[Hernández-Leo, 06]	BSCW, and Quest	Computer network protocols	Motivation and reflection	The tools themselves
[Dietrich, 08]	Several tools: UML, Enterprises, Oracle	Advanced Database Concepts	Better understanding of concepts	Not Available/ Unknown
[Hadjerrouit, 05]	Online resources, devoted web-based tools	Software Engineering	Higher performance	Teacher's support
[Lang, 06]	IDE	Introductory computer science courses	Better outcomes than in previous experiences	Handouts
[De-La-Fuente-Valentín, 10]	Moodle and Mobile phones	Introduction to ICT	Not Available /Unknown	Not Available/ Unknown

Table 2: Studies of collaborative learning applied to ICT education

Web_Soc is a web-based tutoring system developed to improve learning performance around recursion programming concepts. The system is based on the principles of Socratic dialogue and its support is complemented by teachers' regulation, when needed [Chang, 03]. Somehow similiraly, SIMDE is a simulator used in a Computer Architecture and Engineering course to teach Instruction Level Parallelism (ILP) [Moreno, 07a; Moreno, 07b]. In this context, Moodle, a platform with a theoretical background in social constructionism [Dougiamas, 03], has also been used as a collaboration framework among students and teachers. Teachers, in this work, are in charge of indicating the learning process. According to the authors, SIMDE leads students to a deeper knowledge, a higher level of motivation, and a better understanding of IPL theoretical concepts. QUEST (Quest Environment for Self-managed Training), also integrated into the Moodle platform, is a software tool developed with the aim of introducing cooperative and competitive workshops in a course on communications networks. Students using the tool obtain better summative assessment results [Regueras, 09].

The Remote Control is an architecture for the integration of tutoring and process scaffolds into existing collaborative learning environments [Harrer, 06]. The system acts as an intermediate device between the learning process management and the collaborative applications. A prototype of the Remote Control combines the Cool Modes application, a collaborative tool framework designed to support discussions and cooperative modelling processes in various domains - including Computer Science, with CopperCore, an engine that interprets pedagogical methods computationally represented with IMS Learning Design. Following a similar strategy of integrating several tools to support collaborative learning in ICT education, [Grigoriadou, 06] proposes the use of Web text-based educational material, educational activities, and a Web-based cache memory simulation program. The simulation program includes an asynchronous Adaptive Communication Tool (ACT). The ACT supports adaptive discussions according to scaffolding sentence templates aligned with the learning outcomes. The evaluation of the integrated system shows that the simulation program and the context of the activities can effectively support the learning process and enhance learning through facilitating a better understanding of computer memory-related concepts. Another case of integrating different purpose tools is followed in [Hernández-Leo, 06]. It uses two computer supported collaborative tools, the Based Support for Cooperative Work (BSCW) and Quest, to support collaborative activities in an undergraduate course on computer networks. The main objective of the proposed activities is focused on facilitating students' reflection on their own learning.

A platform specifically devoted to support learning wireless embedded systems is presented in [Chenard, 08]. The system combines: (1) a scaffolding approach consisting in formal lectures and exercises that were made progressively more complex, (2) a collaborative learning in which students were asked to form groups to propose a solution to a collaborative task, and (3) an individual activity where students elaborate their own solutions. Teaching assistants provide detailed demonstrations and step-by-step tutorials. According to the authors, students show a high interest in the learning methodology implemented by the system, which facilitates them a more rapid ramp-up in embedded programming skills.

Generic tools have been also used in collaborative learning environments to teach ICT concepts. Dietrich, Urban, & Haag [Dietrich, 08] present a course about advanced database concepts in which students use UML diagrams, object manager tools, or Oracle environment. Their results show that students highlight the instrumental role of strategies and activities in the course toward reaching the objectives identified as well as the ability to specify, analyze, apply, implement and demonstrate the use of advanced database concepts. [Hadjerrouit, 05] uses Web technologies such as online resources, Java and MySQL tools, or interactive web-based database applications to provide support to the learning process in a software engineering course. The teacher acts as a facilitator and guides students on the side when formulating their solutions. Results of applying such method show that overall performance of the students is higher than in previous experiences.

The use of Integrated Development Environments (IDE) in conjunction with collaborative learning strategies is also identified in the literature review. In particular, [Lang, 06] reports the application of an IDE to introductory Computer Science courses whose lab sessions are focused on promoting group-based problem-solving skills. The proposed activities are based on hands-on experiences supported by handouts that include the laboratory objectives, description of the activities, references to supplemental materials, etc.

A work of a different nature is presented in [De-La-Fuente-Valentín, 10]. It uses handheld devices to combine mobile-based activities with in-class sessions to achieve a collaborative activity framed in an Introduction to ICT course. The activity consists of three phases: (a) an individual exploration of the campus' buildings by using NFC tags and mobile phones, (b) presentations of small groups of students that have visited the same buildings during the exploration phase, (c) a review of all presentations to reflect about the campus.

3.2 Studies of Problem-based Learning in ICT education

Problem-based Learning (PBL) is a learner-centred instructional approach underpinned by social theory and the constructivist approach which empowers learners to: think critically; analyze and solve complex real life problems; find, evaluate and use appropriate learning resources; work collaboratively; demonstrate effective communication skills; and become lifelong learners [Baturay, 10]. The basic premise is that Problem-based Learning is "a way of constructing and teaching courses using problems as the stimulus and focus for student activity' with the aim that students acquire 'knowledge and skills through a staged sequence of problems presented in context" [Pearson, 06].

Three basic principles differentiate PBL settings from those that do not implement this methodology. First, it is necessary to have a problem to trigger learning. Second, PBL is not an instructional technique in isolation; rather, it is a holistic approach involving interaction of several learning approaches and methods. Third, PBL is almost always student-centred. These principles offer the opportunities to actively process information, trigger prior knowledge, have a meaningful content, and research and organize information [Sendag, 09]. Table 3 shows the identified research studies that used devoted supporting tools in ICT-related problem-based learning scenarios.

Studies	**Tools applied to ICT Ed.**	**ICT or related areas**	**Learning benefits**	**Scaffolding approach**
[Baturay, 10]	Web-based learning environment (i.e. LMS)	Introduction to computers	Higher scores, and students felt much more ‘connected’ to other class members	Integration of several tools in a learning environment + teacher’s guidance
[Ozturk, 09]	Network in a Box (emulator)	Networking	Improvement in the quality of learning	Not Available/ Unknown
[Papastergiou, 09]	Computer game	Computer memory methods	Effectiveness in promoting students’ knowledge, and students more motivated	The game itself + teacher’s help
[Muñoz-Merino, 09]	Software module for providing hints	Computer architecture, communications software and information servers	Motivation	Hint embedded in the software module
[Kordaki, 10]	LECGO	Programming C	Improvement in students’ performance	LECGO itself
[Garcia-Robles, 09]	Moodle	Parallel Systems Architecture	Improvements in the students’ competences and abilities	Moodle + Facilitators’ help

Table 3: Studies of Problem-based Learning applied to ICT education

[Ozturk, 09] describes the implementation of a live network emulator in a computer network course. The tool, called Network in a Box (NiB), emulates a network between a client and server application. The project increases student participation and improves the quality of the learning. [Papastergiou, 09] uses a computer game, called LearnMem1, in a course for learning computer memory concepts. The game, in the form of mazes, allows access to web-based learning material, and offers the opportunity to search and discover information, to engage in problem-solving activities, to reflect about the presented concepts and to test the students’ understanding. Teachers also provide procedural help to the students. Their results show that the gaming approach is both more effective in promoting students' knowledge of computer memory concepts and more motivational than using a non-gaming approach. [Muñoz-Merino, 09] describes a software module, implemented into XTutor using the Python programming language. It provides hints along the PBL process. The evaluation of this tool in computer architecture, communication software, and information services undergraduate courses show that students perceive the tool as useful and stimulating.

[Kordaki, 10] presents a computer-based problem-solving environment named LECGO (Learning Environment for programming using C using Geometrical Objects). LECGO was designed for beginners in C programming, it includes a presentation of appropriate content for learning fundamentals in C programming and a part dedicated to the learning activities that have to be actively performed by students. A case study shows that students perform successfully the given tasks, reflect on their solutions, engage more in the task and are able of asking more complex questions.

Non-specific tools have also been used in problem-based learning environments. [Baturay, 10] investigates the effects of a web-based learning environment, which consists of a set of integrated tools (e.g.: content management tools, assessment tools, communication and collaboration tools), aimed at enabling students to undertake basic computer applications similar to real workplace cases. These tools also allow instructors to provide consultancy and guidance to students. The results of this study indicate that students get higher scores and feel much more 'connectedness' to other class members. [Garcia-Robles, 09] uses Moodle to implement a PBL method in a course on parallel system architectures. The method was initially described by the teachers using the IMS Learning Design specification, the pedagogical rationalise aimed at facilitating students' development of specific skills in the course area.

3.3 Studies of Project-based Learning in ICT education

Project-based Learning (also with the acronym PBL, meaning Project-based Learning within the context of this subsection) is a comprehensive approach that organizes learning around projects [Thomas, 00] to engage students in investigation of authentic problems. In PBL methods students learn to face realistic, complex problems, rather than academic, simplified tasks, while they develop skills for autonomous learning and group work [Martínez-Monés, 05]. Project-based approaches consist of two primary components [Land, 00]: (a) learners generate a question or problem that serves to organize and drive learning needs; and (b) learners produce a final product or series of products to address the driving question or problem derived. A Summary of studies that have applied Project-based Learning in conjunction with software tools is shown in Table 4.

Studies	Tools applied to ICT Ed.	ICT or related areas	Learning benefits	Scaffolding approach
[Martínez-Monés, 05]	Simulators and collaboration tools	Computer Architecture	Learning deeper and broader, self-organization and planning, collaboration skills	Teacher's assistance
[Davenport, 00]	Delphi and course Webpage	Programming (Pascal)	Not Available/ Unknown	Not Available/ Unknown
[Dos Santos, 09]	Moodle	Software Engineering	Improvement in students' professional performance	Moodle + Teacher's monitoring
[Kim, 09]	LEGO Mindstorm, ANSI-C programming environment	Embedded Systems	Motivation, and improvement of programming skills	Teacher's assistance
[Shankar, 00]	MATLAB	Wireless communications	Better understanding of the field	Not Available/ Unknown

Table 4: Studies of Project-based Learning applied to ICT education

[Davenport, 00] describes the integration of Delphi, a visual programming environment, into an introductory programming course. Besides, a course webpage provides a convenient means for coordinating the course, ensuring that all instructors, assistants and students, know what was required for them each week. Instructors also provide detailed written feedback to students. Results of using this approach indicate that students have understood and appreciate the essentials of engineering design, highlighting that the course successfully fulfilled its objectives. [Dos Santos, 09] uses a Moodle platform for providing an environment based on Software Factory in which students are immersed in practical software development projects. Also, the teacher acting as a Software Factory Monitor is the responsible for tracking the development of software factories and conducting the tracking process. Results from an evaluation show improvements in the students' professional performance. [Kim, 09] uses LEGO Mindstorm to introduce undergraduate students to embedded systems. The course comprises a set of lectures to explain ANSI-C commands related to LEGO Mindstorms, three homework assignments to understand the main characteristics of embedded systems, and three projects consisting in building the embedded systems. A teacher assistant also helps students whenever necessary. Results from a survey show students more motivated and students' programming skills were improved. Martínez-Monés et al. [Martínez-Monés, 05] use different simulators in order to evaluate the different approaches performed by the students. Computer-supported collaborative tools are also used to encourage collaboration, in an undergraduate computer architecture course. Teachers assist the progress of the students, guide students in their decisions and bring into focus important issues that may have been disregarded. Results of this study show a deeper and broader learning, a better self-organization and plan, as well as students develop skills related to collaboration. Shankar & Eisenstein [Shankar, 00] use MATLAB in a course in wireless communications in combination of lectures, homework and projects based on a hands-on approach. Results show that this kind of approach helped students more in understanding the concepts related to this field.

3.4 Studies of Cognitive Apprenticeship in ICT education

Cognitive Apprenticeship is a pedagogical approach characterized by learning-through-guided-experience in cognitive and meta-cognitive where an instructor models and coaches a student to perform a specific task rather than by lecturing [Huang, 05; Murray, 03]. There are six instructional methods of Cognitive Apprenticeship originally proposed by Collins, Brown, & Newman [Collins, 89] consisting in observing an expert's while performing a task and then performing a specific problem-solving process related to a specific issue. Instructors also provide coaching and scaffolding to students during the learning process. Table 5 shows the identified studies that have applied Cognitive Apprenticeship in ICT education.

Studies	Tools applied to ICT Ed.	ICT or related areas	Learning benefits	Scaffolding approach
[Huang, 05]	Customized forums, Jude, Atutor	Software Engineering	Not Available/ Unknown	Teacher's management
[Murray, 03]	Web-based database tool	Database Engineering	Improvement in students' performance	The Web-based database tool itself
[Du, 08]	Expert system shell	Elementary Artificial Intelligence	Improvement in analysis, thinking and judgement.	Teachers' guidance
[Hazeyama, 05]	Devoted Learning Environment	Object-Oriented Software Engineering	Not Available/ Unknown	The environment itself

Table 5: Studies of Cognitive Apprenticeship applied to ICT education

[Du, 08] uses a simple expert system shell focused on the topic of Reasoning and Expert Systems, within an elementary Artificial Intelligence course. Teachers apply specific strategies and then guide students when performing similar problem-solving activities. Expected learning benefits are related to an improvement in student' analysis, thinking and judgement in the subject matter.

[Hazeyama, 05] develops a learning environment based on the Cognitive Apprenticeship model for a object-oriented software engineering course. Somehow similarly, [Huang, 05] presents ADDIE (Analysis, Design, Develop, Implement, and Evaluate), a model to be applied to a Software Engineering course. To support both the course tasks and the learning process, the model combines the use of diverse tools, such as customized online forums, Jude (a java open source UML tool), or Atutor (an open source SCORM/IMS compliant learning content management system). SCORM is a set of technical standards for e-learning software products that allows to import and reuse of structured pedagogical objects [Gonzalez-Barbone, 10], while the IMS Learning Design specification provides a generic and flexible language to computationally express many different pedagogies [Koper, 04]. The instructor is the responsible for managing the students' projects and doing instruction and directing course design.

[Murray, 03] develops a Web-based Database Education tool for the knowledge and skills of database students utilizing scaffolding and activity theory. The development process consists of several stages (i.e. design, implementation, deployment, optimisation, and extension) that students have to address in order to successfully implement the proposed project. Results from an evaluation show improvements in students' performance, and a strong overall acceptance of the tool.

3.5 Other Studies of Constructivist Learning Methods based on Constructionist theory in ICT education

Other studies that have applied other constructivist learning methods in ICT areas are summarized in Table 6. One of them is Inquiry-based Learning (IBL), which is an educational approach that helps learners to seek for truth, information, or knowledge by questioning [Chan, 07]. It involves reviewing information about what is known about a problem, gathering additional information, proposing solutions or explanations, and communicating or acting on the results [Rursch, 10]. As an instructional framework, classroom inquiry is often depicted as a set of recurring learning events commonly referred to as the inquiry cycle, which include stages during which students [Audet, 05]: (a) ask an answerable question or identify a researchable problem; (b) develop a plan and take some form of action; (c) gather resources; analyze and summarize information; (d) draw conclusions and report findings; and, (e) reflect on the process.

[Chan, 07] uses WebQuests, a web-enabled inquiry-based pedagogical tool proposed by Dodge [Dodge, 97], for applying IBL. The approach facilitates the teaching and learning of queuing theory in an undergraduate course, named Simulation and Statistical Analysis. Instructor also applies various constructivist strategies to provide coaching supports to students such as collaborative learning and assessment rubrics. Results from quantitative surveys show positive and significant increase in students' level of interests in studying queuing theory and simulation topics.

IBL has also been used in IT-Adventures [Rursch, 10], an extracurricular activity to increase the interest in and awareness of IT among high school on the areas of cyber defence, game design programming, and robotics. Different challenges were presented to students: (a) to configure, in the cyber defence venue, a set of four computers which present security vulnerabilities; (b) to design, in the game design venue, educational games to teach some concepts in the areas of science, technology, engineering, or math (STEM) by using the Alice platform; and (c) to design and programming a sumo wrestling robots using the LEGO Mindstorms platform. Books, DVDs, or documents with step-by-step instructions are also provided to students.

Studies	**Tools applied to ICT Ed.**	**Learning method**	**ICT or related areas**	**Learning benefits**	**Scaffolding approach**
[Chan, 07]	WebQuest	Inquiry-based learning	Queuing Theory	Increase in students' level of interests	WebQuest itself, instructor's coaching
[Rursch, 10]	Alice and Lego Mindstorm	Inquiry-based learning	Cyber defence, Game design programmin g, robotics	Not Available/ Unknown	Different types of resources
[García, 04]	CASE Tools	Worksho p-based learning	Software Modelling Techniques	Improvemen t in modelling concepts	Teacher's help
[Somerwell , 04]	Similar interfaces	Case-based Learning	Human-Computer Interaction	Better results in class participation, student perception, and long-term retention	Different types of resources

Table 6: Studies applying other constructivist learning methods to ICT education

[García, 04] presents the use of particular CASE tools in a workshop-based approach. This approach introduces problem solving, cooperative learning, and debate as its key aspects applied to software modelling practical class of a first software engineering. Every session is devoted to solving a modelling problem using a concrete modelling technique, followed by a discussion of a proposed solution in a debate moderated by the teacher. As a result, students improve their modelling concepts.

[Somerwell, 04] describes class meetings that employ case-based activities in an undergraduate Human-Computer Interaction (HCI) course. The authors determine tradeoffs relating to student participation, preparation characteristics, and short- and long-term learning outcomes. They also present a case method teaching characterized by presenting cases to students as problem statements and organizing class discussions around the cases [Weaver, 94]. In particular, the authors use contemporary articles, professional cases materials, familiar interfaces, on-going development projects, and a jigsaw approach to facilitate understanding about how materials could be used to support case method teaching of HCI.

3.6 Discussion

This section has described several constructivist learning methods applied to ICT education. In particular, we have noticed that the most representative learning methods (Research question 1) are Collaborative Learning, Problem-based Learning, Project-based Learning, and Cognitive Apprenticeship. These methods have been successfully applied to specific ICT areas such as computer architecture, programming, networking, or math. Overall, students tend to acquire a deeper and a better understanding of the tackled concepts, improving their performance, and reaching better learning outcomes (Research question 3).

Regarding supportive learning tools, we have observed that there is a tendency of using videogames and simulations to engage students in the learning process (Research question 2). Currently, there is a great amount of game engines (e.g.: Unity3D, Torque, XNA, Game Maker, Scratch, Game Salad, Atari-Lite C, Platinum Arts Sandbox) that facilitate the creation of 2D and 3D games. This suggests the emergence of game engines may favour the creation of videogames and simulations over than other types of supportive technological approaches. Also, we have seen that when technology is used to model the learning flow of the different activities, learning management systems (LMS) such as Moodle, are typically used for this purpose. The literature review also brings to light that the use of generic or devoted supportive tools is directly dependent on the available software engines or platforms.

Moreover, these studies show that instructors play an important role in these learning scenarios. In most of cases, teachers are responsible for providing help and guidance to students in order to properly use the supportive tools. This could be attributed to the fact that current tools seem not to provide enough support, help and guidance to students to be properly used in an autonomous way. That is to say, most of the tools do not provide the necessary mechanisms to guide students during the learning process and, for this reason teachers are responsible for assisting, guiding and supporting learners along the learning activities. In this line, a derived research issue is to understand the interest of integrating scaffolding techniques into tools that allow students to properly use the specific tools and enhance their learning experience. For this reason, in the next section we further analyse how scaffolding techniques have been applied in the retrieved studies, paying attention to what extent scaffolding techniques are present in the learning process (Research question 4).

4 Trends of applying scaffolding in ICT education

According to Yelland & Masters [Yelland, 07], scaffolding is generally attributed to Wood et al. [Wood, 76] who describe it as a “process that enables a child or a novice to solve a problem, carry out a task, or achieve a goal which would be beyond his unassisted efforts (p.90)”. Also Wood et al. [Wood, 76] refer to the scaffolding process as the helpful interactions between teacher and student that enable the student to do something beyond his or her independent efforts. Besides, this term emerge from the ideas of Vygotsky’s [Vygotsky, 78] vision of zone of proximal development

(ZPD). ZPD is described as the distance between the actual developmental level, determined by independent problem solving, and the level of potential development, determined through problem solving under adult guidance, or in collaboration with more capable peers. Thus, the distance between learner's actual and potential development is decisive to promote scaffolding.

According to An [An, 10], scaffolds can take various forms, including question prompts, expert modelling, expert advice, learner guides, resources, and tools. Besides, Ge [Ge, 01] concludes that scaffolding strategies, such as coaching through prompts and guiding students to self-generate questions, may promote comprehension, monitor cognitive thinking, and facilitate general problem-solving and reflective thinking. These supports may also include the following: resources, a compelling task, templates and guides, guidance on the development of cognitive and social skills [Demetriadis, 08], tools where a scaffolding device such as a cue card is provided for the learner, strategies that the teacher implements in order to support a learner, and online via techniques such as visual cueing, links to web-pages with directions, downloadable help pages and communication forms to contact the instructor or peers [Yelland, 07]. These supports are gradually removed as students develop autonomous learning strategies, thus promoting their own cognitive, affective and psychomotor learning skills and knowledge.

From the analysis of the studies we differentiate diverse types of scaffolding techniques applied in ICT engineering education. We differentiate when scaffolding is provided by individuals or systems, and is devoted to support either whole activities' flows or specific tasks. For this reason, and in order to answer the Research question 4, we provide a set of scaffolding-related definitions drawn on the scaffolding approaches identified in the studies. These definitions will allow us to classify the studies according to the applied scaffolding approach (see Figure 1).

We differentiate two types of scaffolding depending on the granularity level of the learning process that have been applied:

a). Macro-scaffolding denotes pedagogical methods or teachers' strategies defining flows of coarse-grained activities that provide guidance on how to approach different learning tasks or problems. In that way, constructivist learning methods can be considered scaffolding techniques. These learning methods define the activity workflow that must be followed by learners in order to achieve the defined learning outcomes (e.g. [Abe, 04; Hadjerrouit, 05; Harrer, 06; Hernández-Leo, 06; Regueras, 09]).

b). On the contrary, micro-scaffolding is intended to provide scaffolds for solving detailed actions that enable the resolution of specific activities. Micro-scaffolding may be implemented, for instance, using hints (e.g. [Muñoz-Merino, 09]); or offered by instructors coachers (e.g. [Chan, 07]) or mediators (e.g. [Moreno, 07a; Moreno, 07b]).

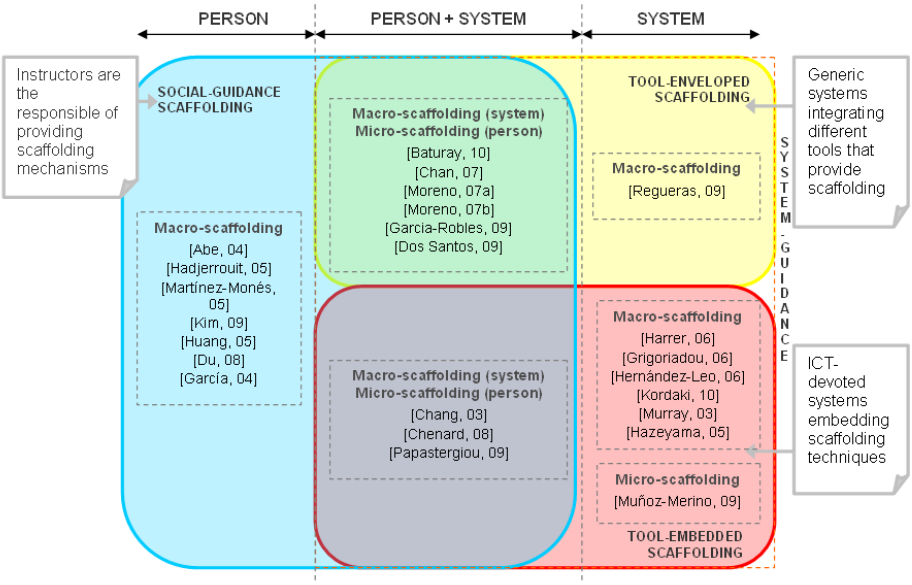

Figure 1: Graphical classification of the retrieved studies according to the identified scaffolding approaches

Considering the guidance support offered to a learner, we differentiate between:

a). Social-guidance scaffolding, when teachers or more knowledge peers are responsible for supporting the learning process either by guiding students (e.g. [Chenard, 08]), assisting students (e.g. [Abe, 04; Kim, 09]), or acting as a mediator (e.g. [Moreno, 07a; Moreno, 07b]);

b). and system-guidance scaffolding, when technological approaches or environments support students during the different learning process by means of, for instance, videogames (e.g. [Papastergiou, 09]), learning management systems (e.g. [Baturay, 10; García-Robles, 09; Moreno, 07a; Moreno, 07b]), modelling tools or simulators (e.g. [Grigoriadou, 06]).

When system-guidance scaffolding is applied during the learning process, we notice that two different implementation approaches have been followed:

a). On the one hand, we use the term tool-embedded scaffolding, when ICT-devoted tools, such as simulators, implement macro- or micro- scaffolding techniques with the aim of supporting learners to achieve the expected learning objectives (e.g. [Harrer, 06; Hazeyama, 05; Kordaki, 10; Muñoz-Merino, 09; Murray, 03]).

b). On the other hand, when generic tooling, such as Learning Management Systems (e.g. Moodle), is used as a part of the whole learning process and integrates specific ICT-devoted tools intended to scaffold specific actions within this learning process, we use the term tool-enveloped scaffolding (e.g. [Regueras, 09]).

Accordingly with the concepts defined, Table 7 shows the studies that have applied scaffolding techniques according to their granularity, guidance support and implementation mode.

Studies	**Granularity (macro vs. micro)**	**Guidance support (system vs. social)**	**Implementation mode (embedded vs. enveloped)**
[Baturay, 10]	Micro (Guidance)	Social guidance (Instructor's guidance)	N/A
	Macro (PBL)	System guidance (LMS)	Enveloped scaffolding
[Chan, 07]	Micro (Coaching)	Social guidance (Instructor's strategies)	N/A
	Macro (IBL)	System guidance (WebQuests)	Enveloped scaffolding
[Abe, 04]	Macro (CL)	Social guidance (Instructor and teaching assistant)	N/A
[Chang, 03]	Micro (Observations)	Social guidance (Teacher's guidance)	N/A
	Macro (CL)	System guidance (Web-based tutoring system)	Embedded scaffolding
[Moreno, 07a; Moreno, 07b]	Micro (Mediation)	Social guidance (Professors' mediation)	N/A
	Macro (CL)	System guidance (Moodle and simulator)	Enveloped scaffolding
[Regueras, 09]	Macro (CL)	System guidance (Moodle and QUEST)	Enveloped scaffolding
[Harrer, 06]	Macro (CL)	System guidance (Remote controller)	Embedded scaffolding
[Grigoriadou, 06]	Macro (CL)	System guidance (Web-based environment and simulator)	Embedded scaffolding
[Chenard, 08]	Macro (CL)	System guidance (specific teaching platform)	Embedded scaffolding

	Micro (Demos)	Social guidance (Teaching assistants)	N/A
[Hernández-Leo, 06]	Macro (CL)	System guidance (BSCW & Quest)	Embedded scaffolding
[Hadjerrouit, 05]	Macro (CL)	Social guidance	N/A
[Papastergiou, 09]	Micro (Help)	Social guidance (Help from teachers)	N/A
	Macro (PBL)	System guidance (Computer game)	Embedded scaffolding
[Muñoz-Merino, 09]	Micro (Hints)	System guidance (Software providing hints)	Embedded scaffolding
[Kordaki, 10]	Macro (PBL)	System guidance (LECGO)	Embedded scaffolding
[Garcia-Robles, 09]	Micro (Help)	Social guidance (Facilitator's help)	N/A
	Macro (PBL)	System guidance (Moodle and IMS)	Enveloped scaffolding
[Martínez-Monés, 05]	Macro (PrjBL)	Social guidance (Teachers' guidance)	N/A
[Dos Santos, 09]	Micro (Tracking)	Social guidance (Teacher's tracking)	N/A
	Macro (PBL)	System guidance (Moodle)	Enveloped scaffolding
[Kim, 09]	Macro (PrjBL)	Social guidance (Teacher's assistance)	N/A
[Huang, 05]	Macro (CA)	Social guidance (teacher's management)	N/A
[Murray, 03]	Macro (CA)	System guidance (A web-based DB tool)	Embedded scaffolding
[Du, 08]	Macro (CA)	Social guidance (Teacher's guidance)	N/A
[Hazeyama, 05]	Macro (CA)	System guidance (Learning environment)	Embedded scaffolding
[García, 04]	Macro (WBL)	Social guidance	N/A

Table 7: Uses of scaffolding techniques in the selected studies

Several groups or clusters can be made from the analysis of this table:

- [Abe, 04] applies a macro-scaffolding approach to a collaborative learning method for dealing with processor organization, compiler design, and computer networking. Social-guidance scaffolding leaded by an instructor is used to guide the activity flow defined by the methodology. Similar studies are [Du, 08; García, 04; Hadjerrouit, 05; Huang, 05; Kim, 09; Martínez-Monés, 05].
- [Kordaki, 10] describes a macro-scaffolding approach for problem-based learning for beginners in C programming. In this case, system-guidance scaffolding via a devoted learning environment tool has been provided. Thus, tool-embedded scaffolding has been used since the tool itself embeds all the functionalities to perform the activities according to a problem-based learning approach. Research studies in this line are [Harrer, 06; Hazeyama, 05; Hernández-Leo, 06; Murray, 03].
- [Regueras, 09] is an example of applying macro-scaffolding to the activity flow defined by collaborative learning environment. System-guidance scaffolding has been used by using a general software environment to guide the activity flow (i.e. Moodle platform). In this example, Moodle integrates QUEST to scaffold different activities of the learning process. For this reason, tool-enveloped scaffolding has been applied since different tools are used to support the different activities.
- C [Chan, 07] applies a macro-scaffolding technique implemented for an Inquiry-based Learning methodology by using enveloped-system guidance by means of WebQuest. Social guidance is provided by teachers in a way of coaching students by using various constructivist strategies. Similar works that have applied same scaffolding techniques are [Dos Santos, 09; Baturay, 10; Garcia-Robles, 09; Moreno, 07a; Moreno, 07b].
- [Muñoz-Merino, 09] is an example of applying micro-scaffolding by implementing hints within a Problem-based Learning environment. Hints are applied in a particular ICT-devoted software approach. This means that embedded system guidance scaffolding has been used.
- [Papastergiou, 09] presents a macro-scaffolding technique implemented for a Problem-based Learning methodology by using embedded-system guidance in a way of a computer game to for learning computer memory concepts. Also, teachers provide both social-scaffolding guidance and micro-scaffolding by offering procedural help. Similar works are [Chang, 03; Chenard, 08].

4.1 Discussion

The classification of the studies according to the different types of scaffolding enables an analysis useful to gain an understanding of the current status around the use of scaffolding in ICT education. Also, it brings out relevant research issues. In the analysis we have considered separately those studies that have applied only macro-scaffolding or micro-scaffolding from those that have applied both macro- and micro-scaffolding together since these different situations can affect the scaffolding implementation needs. In other words, learning scenarios that use both types of scaffolding imply more implementation requirements (than those applying only macro-scaffolding), influencing the decisions regarding the use of system or social and embedded or enveloped scaffolding approaches.

If we do not consider the studies that use both macro- and micro- scaffolding, we can observe that a 50% of the studies providing macro-scaffolding use a social guidance approach [Abe, 04; Du, 08; García, 04; Hadjerrouit, 05; Huang, 05; Kim, 09; Martínez-Monés, 05]. This fact leads us to think that systems do not scaffold the learning process and do not provide enough guidance support to students. As a consequence, teachers are the responsible for assisting the learning process.

It is interesting to see that within the studies implementing system-guidance macro-scaffolding, an 85% embed the scaffolding in specific ICT-devoted tools [Grigoriadou, 06; Harrer, 06; Hazeyama, 05; Hernández-Leo, 06; Kordaki, 10; Murray, 03]. The remainder 15% (i.e. [Regueras, 09]) apply instead enveloped scaffolding using learning management systems or generic standard compliant systems. These results show that general management systems seem to not satisfactorily address the needs of ICT education subject matters. Also, in general when macro-scaffolding is implemented with systems the solution preferred is to embed the scaffolding in devoted tools.

When both macro- and micro- scaffolding have been applied together, all the studies applied social-scaffolding guidance at a micro level and system-scaffolding guidance at a macro level [Dos Santos, 09; Baturay, 10; Chan, 07; Chang, 03; Chenard, 08; Garcia-Robles, 09; Moreno, 07a; Moreno, 07b; Papastergiou, 09]. This data denotes a tendency suggesting that instructors using macro-scaffolding systems are typically also the responsible for verbally providing support at a lower level to help students in the completion of concreted subject-matter tasks. In these cases, the 63% of the studies followed a tool-enveloped scaffolding approach either implemented by a learning management system or a generic standards compliant system [Dos Santos, 09; Baturay, 10; Chan, 07; Garcia-Robles, 09; Moreno, 07a; Moreno, 07b]. Only, a 37% of studies combining social and system guidance provide macro-scaffolding embedded in ICT-devoted tools [Chang, 03; Chenard, 08; Papastergiou, 09]. This result seems to contradict the finding discussed in the previous paragraph. However, it is reasonable to formulate a hypothesis saying that it is difficult for instructors to have a system implementing both types of scaffolding according to their needs. In this line, when the task-dependent scaffolding is provided at a micro-level, it is valid for teachers to apply general systems able of implementing common macro-scaffolding methods enveloping the use of ICT devoted tools. The study of this hypothesis deserves further research. Other research questions derived from this study are: Why there is a lack of ICT-devoted tools embedding the implementation of micro-scaffolding when they are enveloped in macro-scaffolding processes? Do the flexibility requirements of micro-scaffolding (e.g., personalizing the support, changing the scaffolding on the fly, etc.) constrain the decision of implementing the scaffolding in systems? How should ICT-devoted tools be designed and developed in order to provide micro-scaffolding when combined with macro-scaffolding? The study of these hypotheses and research questions deserve further research. This research will provide more insight towards the identification of the relevant factors to be considered in the design and implementation of potentially effective scaffolding support in the ICT education domain.

5 Conclusions

From a need to shift to constructivist learning methods that encourage lifelong, collaborative, student-centred and self-regulated learning in order to deal with the decreasing interest towards ICT by students, this work has elaborated a literature review showing the most representative work from 2000 to 2010. From a selection of representative journals in ICT engineering education within the field of educational technologies, we retrieved the most representative constructivist learning methods that have been successfully applied to some ICT-related areas (i.e., computer science, computer engineering, information systems, information technology, and software engineering).

In relation to the first question presented at the introduction of this paper about "What are the most representative constructivist learning methods within the field of ICT education?" we notice that Collaborative Learning and Problem-based Learning are the methodologies that have been applied more to ICT education. Followed by this, are Project-based Learning, and Cognitive Apprenticeship. Other constructivist learning methods, such as Inquiry-based Learning, have been used within this field but they are less representative.

The study suggests tendencies indicating "the supportive tools for learning that are being used in order to support those constructivist learning methods to engage students in the learning process" (second question). We can say that, when macro-scaffolding is applied in conjunction with micro-scaffolding, either learning management systems or open source SCORM/IMS compliant learning content management system are the preferred option to implement the activity flow of the different constructivist learning methods. In those cases, students are socially guided at the micro level. On the contrary, the most representative supporting tooling used when macro-scaffolding is used in isolation, is ICT-devoted tools including computer games, simulators, visualization tools, and specific web-based tools with forums and chats. However, these tools do not provide support at the micro-level.

For the question "What are the learning benefits of applying such approaches?", we notice that learning benefits are related with a better and deeper understanding of ICT-related concepts, an improvement in technical skills, an improvement in academic achievements, an increase in motivation because students are closer to the reality, and an increase in social skills since collaboration activities are present in most of this constructivist learning methods.

We propose some scaffolding definitions to answer the last question about "To what extent and how scaffolding techniques are present in the learning process to improve the learning performance?". From the identified research studies, we observe that scaffolding techniques are present in different ways: as a support given by either individuals (social-guidance scaffolding) or systems (system-guidance scaffolding); as a support of whole activities' flows (macro-scaffolding) or specific tasks (micro-scaffolding); and as a support applied within a specific tooling (tool-embedded scaffolding) or when a tool is used as part of a scaffolded learning process (tool-enveloped scaffolding). Besides, social-guidance is more present than system-guidance scaffolding, and because of this, instructors are who most typically guide the activity flow. This result could be attributed to several reasons, which deserve further research, including:

a). it seems there is still a lack of tools satisfactorily implementing constructivist learning methods, and as a consequence instructors themselves provide this support to students;
b). current tools may not be flexible or adaptable enough to address specific learning tasks related to ICT education;
c). the option of using embedded scaffolding in ICT-devoted tools designed according to the needs of a specific learning situation seems to be preferred but the implementation cost is very high;
d). or having an ICT-devoted system integrating macro-scaffolding and micro-scaffolding seems to be very difficult or costly to achieve since the predominant solution is to envelope ICT-devoted tools in a general approach and to delegate instructors the provision of micro guidance.

In conclusion, scaffolding students during the learning process shaped by a constructivist learning method in conjunction with ICT education software tools can provide a good opportunity to engage students. In this context, further research is still needed to address the lack of computer-scaffolded support in ICT-devoted tools when macro- and micro- scaffolding is combined. Furthermore, new lines of research can be derived from this study. The classification and definitions of scaffolding provided in this paper enable researchers to situate existing research and tooling and identify areas for improvement. One specific line of future work that emerges from the analysis has to do with the challenges and possibilities around the design, implementation and evaluation of ICT-devoted tools that properly embed macro- and micro- scaffolding techniques.

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