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Self-Regulated Learning for Web-Enhanced Control Engineering Education

Flavio Manganello[1*], Carla Falsetti[2] and Tommaso Leo[2]
[1]Institute for Educational Technologies, Italian National Research Council, Genoa, Italy // [2]Università Politecnica delle Marche, Ancona, Italy // manganello@itd.cnr.it // c.falsetti@univpm.it // tommaso.leo@univpm.it
[*]Corresponding author

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ABSTRACT

Web enhanced active learning has been demonstrated to be an effective approach in Engineering Higher Education, as it provides students with more flexibility in dealing with the development of skills related to professional knowledge. However, students require a sufficient level of self-efficacy and control over their own learning, which might impact negatively on their effort and academic performance. Therefore, promoting self-regulated learning among students would help them to develop effective strategies they could adopt in planning, monitoring and evaluating their learning process. In this paper, a web-enhanced active learning approach is proposed which integrates a self-regulated learning strategy that supports Control Engineering students in managing their learning process. In order to evaluate the effectiveness of the proposed approach, a three-year quasi-experimental study was performed in the context of an undergraduate Automatic Control course at the Università Politecnica delle Marche, Italy. This involved 418 students and 4 teachers. Both quantitative and qualitative measurement tools were used for the evaluation. The results of the study confirmed the effectiveness of a learning design specifically tailored to implement self-regulated learning features in a web-enhanced active learning approach for undergraduate engineering students. Moreover, the qualitative-quantitative evaluation model proved to be effective in capturing and gauging a more comprehensive and detailed picture of the triggered self-regulated learning dynamics.

Keywords

Engineering education, Material knowledge, Self-regulated learning, Active learning, Web-enhanced learning

Introduction

Over the last few years, researchers and educators in the field of Engineering Education have investigated strategies for actively promoting development of professional knowledge among university students (Llorens, Berbegal-Mirabent, & Llinàs-Audet, 2017; Vallim, Farines, & Cury, 2006). It is recommended that engineering students should be trained to master complex physical phenomena, to acquire competence in the analysis of complex systems in several application domains, and acquire the capacity to develop proper design processes (Robinson, Sparrow, Clegg, & Birdi, 2005). The focus of attention should be on the development of professional skills of an expert designer. One of these is Material Knowledge (MK). According to Leo, Pagliarecci, and Spalazzi (2009), MK is knowledge related to real operation conditions in the engineering of complex systems. MK is possessed by experts; it is compiled, implicit, and can be described as intuitive; it is empirical. In a previous study (Leo, Falsetti, Manganello, & Pistoia, 2010a), it was demonstrated that teaching MK effectively demands active, experiential and collaborative learning processes enacted in supervised learning settings; here, educators act as experts providing students with appropriate scaffolding and facilitation. Nevertheless, such an approach requires teachers to devise and implement relevant learning strategies and give their students more autonomy (Coto, Mora, & Alfaro, 2013); it requires students to mobilize their personal desire to acquire knowledge or proficiency in the competence domain (Leo, Manganello, & Chen, 2010b).

Online technology and web-enhanced learning have demonstrated considerable potential for optimizing the learning process in Engineering Higher Education. They also help students to acquire professional knowledge through active learning strategies, as online activities provide students with more flexibility than traditional campus-based courses (Cabrera, Villalon, & Chavez, 2017; Hoic-Bozic, Mornar, & Boticki, 2009; Garousi, 2010; Lundquist, Skoglund, Granström, & Glad, 2013). However, it is not always evident that use of such flexible technology-enhanced active learning settings leads to the development of the necessary skills. The critical issues can be traced back to the functional characteristics of the environments themselves, the way they are configured and used by the teacher, as well as students' ability to use them. Within such learning settings, students might be challenged by the lack of pedagogical guidance or exposed to information retrieval issues (Dron & Anderson, 2014). This might affect their motivation, effort and academic performance, as students not familiar with such approaches and not sufficiently self-motivated are most likely to experience a decrease in effort and give up. In this light, students using technology-enhanced learning environments should first be engaged in scaffolded practice and then in fading of the guidance (Azevedo & Hadwin, 2005; Beishuizen & Steffens, 2011). It becomes crucial for students to be supported so as to gain confidence within such learning settings, entailing an adequate level of self-efficacy, as well as of control over their own learning (Hartnett, George, & Dron, 2011). Therefore, it is important to promote self-regulatory processes in learning within computer-based learning settings (Azevedo, 2007). Previous studies have demonstrated the positive effects of computer supported self-regulation on learning performance, specifically with reference to mathematics (Cho & Heron, 2015; Kramarski & Gutman, 2006; Lai & Hwang, 2016) and Technology (Santhanam, Sasidharan, & Webster, 2008; Whipp & Chiarelli, 2004), as well as on learning processes, learning outcomes and self-efficacy in the field of Science (Lai, Hwang, & Tu, 2018; Sha, Looi, Chen, Seow, & Wong, 2012).

With specific reference to Engineering Education, few research studies have evaluated self-regulated learning in the context of online and web-enhanced learning. Notably, a previous study investigating engineering students' self-regulated learning skills in web-intensive learning environments demonstrated that students may respond differently with respect to self-regulated learning, thus having an impact on their level of engagement (Lawanto, Santoso, Lawanto, & Goodridge, 2017). Moreover, few research studies have focused on gauging the impact of designing and embedding self-regulated learning prompts in web-enhanced learning settings, or on evaluating the process. As far as the implementation framework is concerned, self-regulated learning has been considered cumulative with active learning in web-enhanced settings (Debnath, Rahman, & Hossain, 2014), although design in particular has been investigated as part of efforts to implement motivational features in reactive blended learning applied to an introductory Control Engineering course (Mendez & Gonzalez, 2011). Both qualitative and quantitative approaches were considered in terms of evaluation methods for describing and analyzing the practice and development of self-regulated learning specifically within digital learning environments; in the former case, a set of self-regulated learning indicators were adopted for spotting clues of self-regulated events within students' messages (Debnath et al., 2014); in the latter case, learning analytics were used to identify patterns in students' decision making about learning with respect to the conditions that might have influenced them (Gašević, Dawson, Rogers, & Gasevic, 2016).

So with the aim of reinforcing the effectiveness of active learning in promoting professional knowledge (in particular MK) among engineering students, and fostering their ability to self-regulate the learning process, in this study a web-enhanced active learning approach was developed. This integrated a self-regulated learning strategy to support students in managing their own learning pace, monitoring their effort investment and their performance, and making decisions about the strategies they adopt when seeking help and information. It was expected that this approach would support students in reflecting on and evaluating their learning performance. Moreover, a specific quali-quantitative evaluation method was implemented for recognizing and gauging the practice and development of self-regulated learning within the approach.

Literature review

Active learning

Active learning is grounded in constructivist learning (Anthony, 1996) and is tightly linked to learning through discovery (Bruner, 1961) and learning through meaningful reception (Ausubel, 1978). In an active learning setting, students actively engage in a knowledge building process within lessons, which are student-centred rather than teacher-based. Moreover, the process of knowledge creation relies on students' prior knowledge, where students are self-aware of the process at a cognitive level and can control and regulate it themselves. That is, activation and recognition of prior knowledge are crucial tasks when designing an active learning scenario. A typical learning strategy for fostering students' active learning is problem solving (Kapur, 2010). Within Science, Technology, Engineering, and Mathematics (STEM), active learning has been shown to be more effective than traditional lectures in promoting both comprehension and memory, and in enhancing student performance (Freeman et al., 2014). As far as Engineering Education is concerned, a study conducted by Prince (2004) defined common, relevant forms of active learning and found that there is broad support for the core elements of active, collaborative, cooperative and problem-based learning.

Technology tools and multimedia adopted within active learning settings have proven effective in engaging and motivating students, as well as in improving their learning processes (Huizenga, Admiraal, Akkerman, & Dam, 2009; Moreno & Mayer, 2000). However, not all students are necessarily comfortable with an active learning approach, especially those with weaker control of their learning process (Margolis & McCabe, 2004). Hence, further investigation is needed to understand the way students self-regulate in such active learning settings, as well as the most appropriate mechanisms or tools for promoting self-regulation strategies.

Self-regulated learning

Self-regulated learning (SRL) is considered "the self-directive process by which learners transform their mental abilities into academic skills" (Zimmerman, 2002, p. 65). SRL occurs in a pro-active way and consists in controlling the learning process not only at the cognitive, metacognitive and behavioural levels, but also in terms of motivation and emotions. According to Zimmerman (2000; 2002), SRL is a recursive process characterized by three different phases, as shown in Figure 1: forethought, performance, and self-reflection. In the forethought phase, students set their learning goals, select the suitable learning strategies, and make an initial assessment of their capacity to reach the goals (self-efficacy) and to activate their prior knowledge. In the performance phase, students monitor their learning process in terms of maintaining attention, use of self-learning strategies, management of time, management and/or configuration of the study environment, and possible search for help (help-seeking). In the third phase, students evaluate their learning process, particularly the achievement of learning outcomes with respect to the goals initially set and the strategies selected.

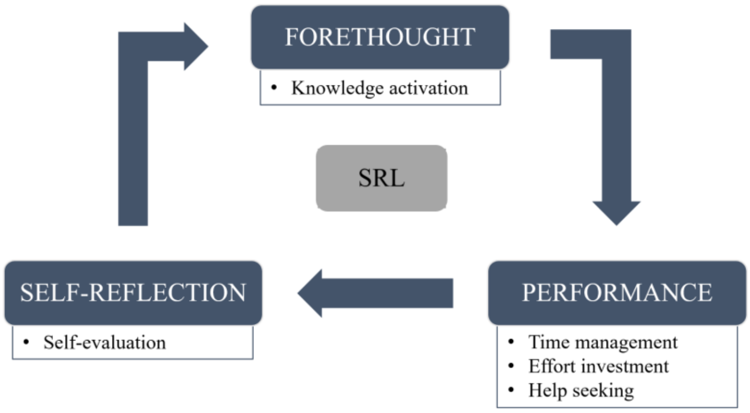

Figure 1. Phases of self-regulation in learning, with a list of the processes considered in this study

In recent years, advancements in technologies have impacted individual learning strategies, and technology-based learning environments play an ambivalent role with respect to SRL skills. While using technologies might sometimes be challenging, at the same time they can offer tools and functionalities allowing or even stimulating the development of SRL skills. With this in mind, several studies have investigated the relationship between SRL and technologies, aiming to understand the potential technologies offer for SRL and the conditions that allow optimal exploitation of such potential. Many of the studies have demonstrated the potential support granted to SRL by student-centered web-based learning environments (Azevedo, Behnagh, Duffy, Harley, & Trevors, 2012; Dabbagh & Kitsantas, 2004), by personal learning environment and social media (Dabbagh & Kitsantas, 2012; Manganello, Falsetti, Spalazzi, & Leo, 2013).

According to the literature, active learning has proven to be an effective approach in Engineering Education, promoting student comprehension and memory, and improving their learning performance (Freeman et al., 2014). Problem-based learning and collaboration strategies have proven effective in fostering active learning among engineering students (Prince, 2004). Furthermore, researchers have demonstrated that students need to be self-regulating within active learning settings, in order to better control their learning process (Margolis & McCabe, 2004). With this in mind, in this study a web-enhanced active learning approach was proposed for fostering SRL among engineering students, aiming at supporting them in managing their own learning pace, in monitoring their effort investment and their performance, and in making decisions about the strategies they adopt for seeking help and information. To this end, the following research questions were investigated so as to evaluate the effectiveness of the proposed approach, in the context of Engineering Higher Education:

- RQ.1a - Can SRL be effectively promoted online among students?
- RQ.1b - Can SRL development online be evaluated and measured?
- RQ.2 - Can SRL be instructionally defined in the actual learning process?

A self-regulated web-enhanced active learning approach

In this study, a self-regulated web-enhanced active learning approach for undergraduate engineering students was developed featuring the Moodle e-learning platform. As shown in Figure 2, the system consists of a learning dashboard, a set of SRL monitoring tools, a teaching dashboard and a database. The learning dashboard provides the students with the learning contents and the learning assignments uploaded by the teacher(s). From the same dashboard, the students can access the course syllabus and the contextualized learning activities (i.e., Blog/Forum/Wiki). The SRL monitoring tools are prompts explicitly and implicitly embedded in the e-learning platform that provide the students with specific affordances to foster the SRL strategy in terms of the following processes: knowledge activation, time management, effort investment, help seeking, and self-evaluation. By means of the teaching dashboard, the teacher(s) can upload the learning material and the syllabus, as well as provide the students with comments and feedback based on their learning process. Finally, the platform's database tracks the students' learning logs and stores their grades in the gradebook.

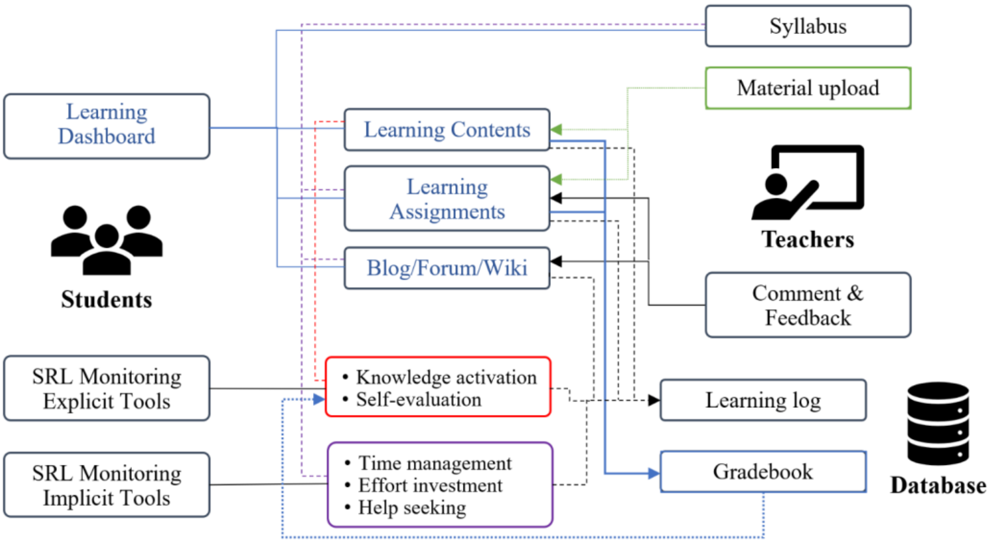

Figure 2. Flowchart of the self-regulated web-enhanced active learning approach

Figure 3 shows the learning procedure of the self-regulated active learning web-enhanced approach. The students engage with learning activities that – implicitly or explicitly – provide them with SRL prompts. SRL features are integrated in the learning path from the beginning, and are embedded into the online learning environment through learning activities and materials. Four teachers are involved: two teachers for the face-to-face classroom activities, one teacher for the laboratory applications, and one teacher for the online activities.

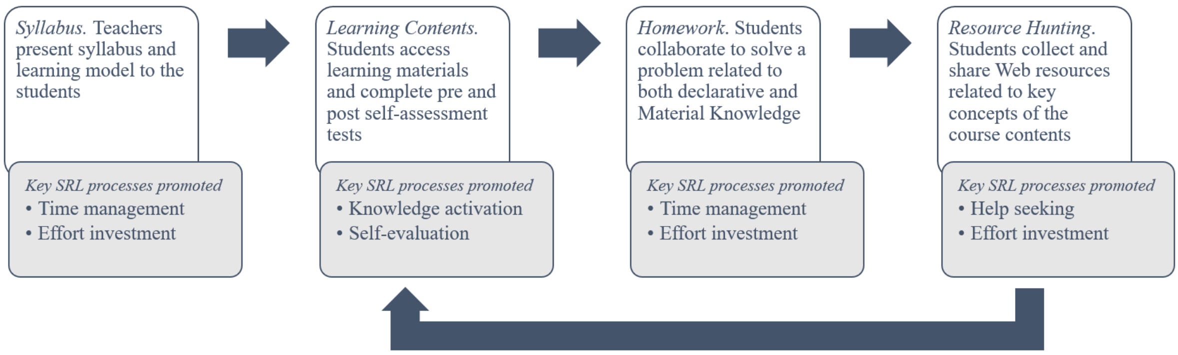

Figure 3. Learning procedure of the self-regulated web-enhanced active learning approach

At the begin of the course, the teachers introduce the syllabus and the learning model to the students, who are left free to decide whether to follow the course in the traditional way or in web-enhanced mode. Presentation of the syllabus is intended to provide students with all the information about the course and help them in taking more responsible decisions about the organization of their learning process (time management, organization, effort investment, etc.).

The students following the web-enhanced approach are asked to log on to the e-learning platform and access the learning contents. These are organized in units, whose weekly scheduling is presented in the syllabus and is aligned to the topics of the traditional course. These learning materials present the declarative knowledge of the discipline and introduce preliminary aspects of the MK (operative instructions on how to manage professional tools - i.e., Immersive Telelaboratory and/or MATLAB). At the beginning and end of each unit, the students are provided with self-assessment tests. Those at the begin of each unit are designed to help students activate prior knowledge, while those at the end are intended for self-evaluating the learning process. After that, the students are led to the supervised learning activities, which consist of weekly homework and resource hunting.

The Homework activities are implemented in Moodle by means of the Assignment activity. Each homework assignment involves solving a problem related to the topics presented at the current time, and hence its complexity increases with time. To promote MK, laboratory experiences are as set as homework. Students are proposed Immersive Telelaboratory and/or MATLAB-based learning activities with the aim of fostering ‘learning by doing’ experiences. The students are asked to work in groups and to schedule their activities week by week. Those interested are invited to form small groups of three people and assume specific roles (i.e., role-playing) (Wenger, McDermott, & Snyder, 2010). Each group is free to take decisions about the roles during the activities, but they were asked to implement a weekly turnover so as to share the workload. Each group is provided with a discussion forum, supervised by the teachers. The aim of running such supervised, well-structured, group-based activities is to promote the SRL strategy (especially in terms of time management and effort investment) among the students in a ‘scaffold and fade-away’ fashion.

In addition to Homework, the students engage in a Resource Hunting activity aimed at familiarizing them with the ‘contextual’ dimension of the domain knowledge and eliciting pre-existing knowledge (Eraut, 2000). The students are asked to use specific Moodle features (i.e., blog, forum, and Wiki) to collect meaningful and contextualized Web resources, share them with others, and provide explanations and comments and/or collaboratively write glossary entries. The aim is to explain key concepts related to the course contents, and to link the entries to meaningful and contextualized Web resources featuring explanations and comments. Moreover, the Resource Hunting activity attempts to promote students’ help-seeking and effort investment in a more autonomous and less structured fashion than in the Homework activity.

After completing both the Homework and Resource Hunting activities, students receive comprehensive feedback from the teachers. Participation in these activities, as well as completion of the learning contents and related self-assessment tests, is not mandatory and not subject to summative evaluation. However, learning contents and Homework are graded as a formative assessment activity, with the aim of helping the students fine tune and reflect on their learning process.

Method

To evaluate the effectiveness of the self-regulated web-enhanced active learning approach in terms of the research questions, a three-year quasi-experimental study was carried out. This was performed in the context of three sequential editions of an Automatic Control course, a compulsory unit of the Information Engineering undergraduate program at the Università Politecnica delle Marche (UNIVPM), Italy. In total, 418 students and 4 teachers were involved. The course design was an iterative process. Each edition comprised a suitable mix of face-to-face lectures/numerical case study presentations and online activities, both supervised and not. Several methods were used to measure and evaluate the approach, including ex-ante survey, ex-post survey, tracking of the learning activities, forum discussion analysis, and interviews with the teachers.

Context of the study

At the UNIVPM, Automatic Control is the only undergraduate course of controls and systems throughout the degree program in Information Engineering. The objective of the course is to prepare students to become skilled practitioners in the field of engineering. The discipline is organized around three knowledge building blocks: how to model the objects to be controlled and then those that will be designed for control; once the model is clarified and the formal definition of the desired performances are explained, the next step is the synthesis of the control law for attaining the desired performance of the whole system; finally, how to operate the control in real or realistic cases so as to acquire the MK through experience using an Immersive Telelaboratory (Leo et al., 2010a) or by simulation using MATLAB. With the teacher’s help, the students are expected not only to acquire basic knowledge of the structured aspects of the discipline, but also to face critical issues drawing on minimal information provided by the teacher. For this purpose, it is necessary to clearly define the problem to map the problem data with regards to the available tools, and to use those tools properly. To achieve this, the course needs to comprise specific learning activities based on collaboration and role-playing. Within this educational setting, learning design and formative assessment become crucial. To this end, a web-enhanced active learning approach has been defined, as illustrated in Figure 4.

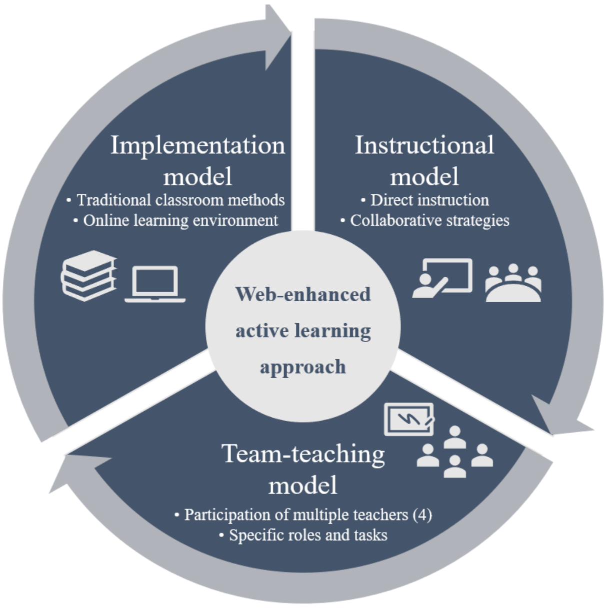

Figure 4. Learning scenario of the self-regulated web-enhanced active learning approach

The implementation model combines traditional classroom methods with an online learning environment; the instructional model integrates direct instruction and collaborative strategies; the team-teaching model reckons on the active participation of multiple teachers, with specific role and tasks, at various stages. The directive approach is mainly used to support the teaching and learning of declarative knowledge through a mix of traditional activities (face-to-face lectures and numerical case-study presentations), access to structured e-learning contents (Battistini et al., 2009), and formative and summative assessment. This approach does not seem to be effective for supporting the acquisition of procedural knowledge in the domain (Spiro & DeSchryver, 2009). Moreover, students to be educated as design engineers of Automatic Control should be engaged in practical activities such as laboratory experiences (blended with theoretical explanations) to attain a more solid grounding in the subject matter (Leo et al., 2010b). Here students are engaged in supervised learning activities in the online environment, where a mix of collaborative and contextualized learning strategies is adopted.

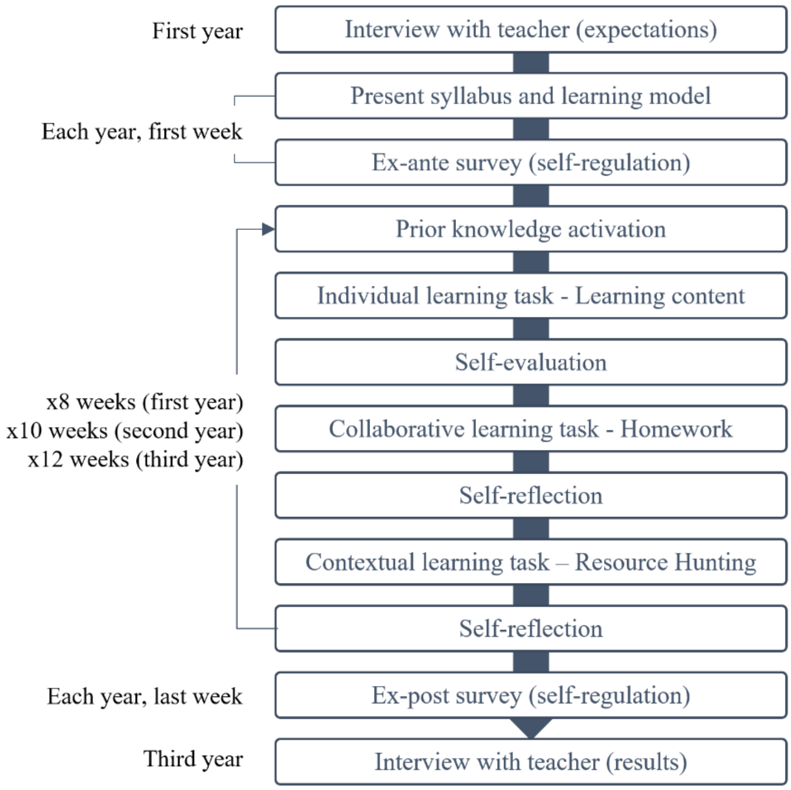

Figure 5. Learning procedure and study design of the self-regulated web-enhanced active learning approach

Within such a course, it is necessary to adopt a team-teaching approach to ensure that students have access to an appropriate mix of authentic competencies. The students are in touch with two teachers, one explaining theory via traditional classroom lectures and the other introducing them to the exercise practice (numerical case-studies). Consistency between the two teachers is a key requisite. When laboratory experiences are planned, a third teacher manages the laboratory equipment. In addition, a fourth teacher is involved as an online facilitator to train and assist the students during the online activities Final examinations are carried out by various examiners, who consider the arguments independently and then work jointly on collegial and specialized evaluation. Coordination among the teachers and the leadership is critical. Behavioral aspects of collaboration and communication are essential (Leo et al., 2010a; Manganello, Falsetti, & Leo, 2009). The learning procedure of the self-regulated web-enhanced active learning approach, along with its study design, is shown in Figure 5.

Participants

Within the three-year period of the study, four teachers were involved: one for the face-to-face lectures, one for the face-to-face numerical case-study presentations, one for the laboratory experiences/MATLAB activities, and one for the online learning activities. A total of 418 students were involved. The number per year was respectively: n = 127 in the first year, n = 138 the second year, and n = 153 the third year.

Measurement tools

Several measurement tools were used to collect data from the three-year period of study and to evaluate the approach. Quantitative tools included ex-ante and ex-post surveys (for each of the three years of the study), and tracking logs of the supervised learning activities (only the Homework activities were considered for this study) on the online platform (for each of the three years of the study); qualitative tools included interaction analysis of student group forum discussions (for each of the three years of the study) and semi-structured interviews with two teachers (one teacher was interviewed at the beginning of the first year study, the other at the end of the third). The evaluation model is presented in Table 1.

Table 1. The evaluation model

Dimensions	Indicators	Measurement tools
SRL-Forethought	Self-motivation	EAS (1 item)
		FDA
		SSI
	Knowledge activation	EAS (1 item)
		FDA
		SSI
SRL-Performance	Time management	EPS (1 item)
		TSLA
		FDA
		SSI
	Help seeking	EPS (3 items)
		FDA
		SSI
	Effort investment	EPS (1 item)
		TSLA
		FDA
		SSI
SRL-Self-reflection	Self-evaluation	EPS (1 item)
		FDA
		SSI

Note. EAS = Ex-ante survey, EPS = Ex-post survey, TSLA = Tracking of the supervised learning activities, FDA = Forum discussions analysis, SSI = Semi-structured interviews.

The ex-ante survey was composed of eight items. With respect to the aims of the study, this survey contributed to collecting students' self-reported quantitative data on the following SRL dimension:

- SRL-Forethought: "self-motivation" (1 item) and "knowledge activation" (1 item), to be evaluated on a four-point scale (1=strongly disagree, 2=disagree, 3=agree, and 4=strongly agree).

The ex-ante survey was composed of 15 items evaluated on the same four-point scale. With respect to the aims of the study, this survey contributed to collecting students' self-reported quantitative data on the following SRL dimensions:

- SRL-Performance: "time management" (1 item), "help seeking" (3 items), "effort investment" (1 item);
- SRL-Self-reflection: "self-evaluation" (1 item).

The Homework group-based activities were tracked and analyzed, based on the logging patterns of the groups that actively participated in the proposed activities within the e-learning platform, week by week, in terms of "submitted Homework" and "role-play." By tracking the related activities in Moodle, quantitative data were collected about SRL events regarding time management and effort investment.

Analysis of interactions in the forum discussions was aimed at collecting qualitative data useful for tracking and measuring self-regulated events within the student groups. The online forum discussions were thematically analyzed according to an interaction analysis model specifically tailored for detecting SRL in online communities (Dettori & Persico, 2008). However, the model for coding the text messages was re-designed according to the three SRL dimensions (and their related indicators) considered in the study, as shown in Table 1. All the messages in the student' group forum discussions for each of the three editions of the course were considered for the analysis. All the messages were collected, and each message was classified by two coders according to 19 coding labels (i.e., nodes) associated to observable SRL-related events. The Nvivo software application was used for data coding and analysis. The coding labels, implemented in Nvivo as "Nodes," are presented in Table 2 below.

The interviews with the teachers were aimed at collecting qualitative data about the six SRL-related indicators presented in Table 1. One teacher was interviewed at the beginning of the study to gauge expectation, while the other was interviewed at the end of the study to gauge outcomes. The interviews were audio-recorded and transcribed verbatim. The analysis was organized as follows: definition of a taxonomy of elements to be used as coding labels; organization of these coding labels in four macro-categories (teaching context, teacher profile, course implementation, and course evaluation); coding of the interviews by two coders according to the defined coding labels. The labels used for coding SRL-related expressions within the two interviews are the same as those used for the forum discussion analysis, presented below in Table 2.

Table 2. Coding labels for forum discussion and interview analysis

SRL dimensions	SRL indicators	Coding labels (Nodes)
Forethought	Self-motivation	• Target goal setting • Goal orientation adoption • Efficacy judgments • Task value activation • Interest activation
	Knowledge activation	• Prior content knowledge activation • Metacognitive knowledge activation
Performance	Time management	• Time planning • Awareness and monitoring of time use
	Help seeking	• Awareness and monitoring of need for help • Help seeking behavior
	Effort investment	• Effort planning • Increase/decrease effort • Change or renegotiate task • Persist, give up
Self-reflection	Self-evaluation	• Cognitive judgments • Affective reactions • Attributions • Evaluation of task • Evaluation of context

Results

The complete dataset compiled over the three-year period of the study comprised:

- n = 179 ex-ante surveys filled out by the students
- n = 121 ex-post surveys filled out by the students
- n = 56 active groups (n = 168 active students) tracked in the supervised learning activities
- n = 1 audio-recorded and transcribed interview with 1 teacher (face-to-face lectures)
- n = 1 audio-recorded and transcribed interview with 1 teacher (numerical case-study presentations)
- n = 220 forum messages collected from the student group discussions forum.

Both the ex-ante survey and the ex-post survey were filled out on a voluntary basis by students who opted for the web-enhanced approach and then enrolled themselves in the online course. On the aggregate for the three years, results were collected from both the ex-ante survey (n = 179) and the ex-post survey (n = 121). The following percentages present the aggregate data for the three years.

The main results of the ex-ante survey analysis are shown in Table 3. With respect to the "SRL-Forethought" dimension, most of the students self-reported to have intrinsic motivation toward the course topics (75.2%); prior knowledge was considered adequate for addressing the activities of the course by just under half of the students (48.8%).

Table 3. Results of Ex-ante survey by SRL dimensions of three years aggregation

SRL-Forethought	S.A.	A.	D.	S.D.	N.A.
I am interested in the topics of this course	57%	18.2%	2.5%	2.5%	19.8
I consider my prior knowledge of the subject adequate for successfully carrying out the activities of this course	23.1%	25.6%	18.2%	13.2%	19.8%

Note. Total respondents = 179. S.A. = Strongly Agree, A. = Agree, D. = Disagree, S.D. = Strongly Disagree, N.A. = Not Answered.

The main results of the ex-post survey analysis are shown in Table 4. With respect to the "SRL-Performance" dimension, most of the students self-reported that scheduling and managing the online activities of the course with the rest of the curricular activities was not an issue (62.8%). Help-seeking was practiced by most of the students, who self-reported that the Homework and Resource Hunting activities made it easier to decide whether to seek assistance (68.8%) and that they looked for peers and/or the online tutor to discuss issues (62.8%). Most of the students enjoyed the proposed group-based activities because they helped each other (69.4%). In terms of effort investment, only 38.8% of the students deemed role-playing to be an effective strategy for self-monitoring the learning process within the group-based activities. With respect to the 'SRL-Self-reflection' dimension, most of the students declared to have exploited the self-assessment tests provided with the learning materials as a benchmark for self-evaluating their progress (62%).

Table 4. Results of Ex-post survey by SRL dimensions of three years aggregation

SRL-Performance	S.A.	A.	D.	S.D.	N.A.
I had no difficulty managing my study programs with the learning activities in this course.	40.5%	22.3%	11.6%	5.8%	19.8%
To find the information I needed to do Homework activities, I used the learning contents and / or asked help from others.	47.9%	20.7%	4.1%	3.3%	24.0%
I looked for a peer and / or for the online tutor to discuss issues.	37.2%	25.6%	9.1%	0.8%	23.1%
I enjoyed the group-based activities because we helped each other.	53.7%	15.7%	5.0%	3.3%	22.3%
My active participation in group-based activities was facilitated by role-playing.	13.2%	25.6%	18.2%	19.8%	23.1%
SRL-Self-reflection	**S.A.**	**A.**	**D.**	**S.D.**	**N.A.**
The self-assessment tests and Homework were useful for monitoring my progress	27.3%	34.7%	12.4%	4.1%	21.5%

Note. Total respondents: 179. S.A. = Strongly Agree, A. = Agree, D. = Disagree, S.D. = Strongly Disagree, N.A. = Not Answered.

As shown below in Table 5, the students who actively carried out the supervised learning activities were 68.3% (n = 168) of the total number of students who started the activities (n = 246). In the first year this percentage was 30.7% (n = 39), in the second year 45.7% (n = 63), and in the third year 43.1% (n = 66). It should be noted that "active groups" are those that completed at least half of the number of the Homework activities proposed during the current edition of the course. The number of Homework activities assigned was eight during the first year, 10 during the second year, and 12 during the third year.

Table 5. Number of active students and active groups

	First year	Second year	Third year	Total
Students self-enrolled in the online course	127	138	153	418
Students who started the activities	69	78	99	246
Students who completed the activities	39	63	66	168
Groups that started the activities	23	26	33	82
Groups that completed the activities	13	21	22	56

As shown below in Figure 6, the year-long response to the Homework activity was similar in each of the three years: in each case, the number of Homework outputs submitted was particularly high in the first half of the year, then decreased significantly in the second half.

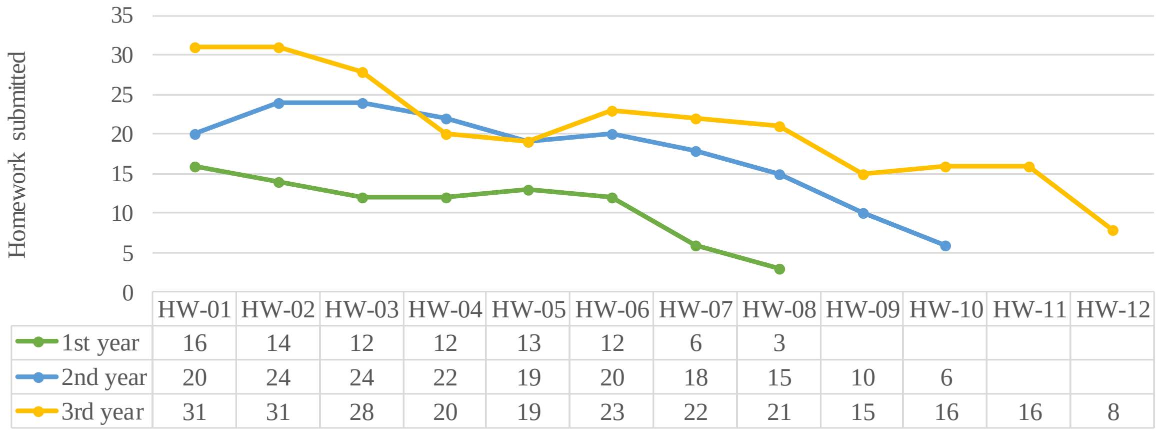

Figure 6. Number of Homework activities completed per year

The diagrams shown in Figure 7, on the other hand, visualize role-playing as a proportion of the various Homework activities. Except for the first year, there was consistency between the group activities and the management of the same through the proposed roles. The data presented in Table 6 show that students actively participated in the group forum discussions. It should be noted that the highest total number of messages ($n = 97$) was observed in the second year, whereas the highest number of active groups with respect to the group-based online activities was observed in the third year. Although the total number of messages per year was heterogeneous, the percentage of messages containing SRL indicators and the average number of indicators per SRL-related message were consistent over the three years.

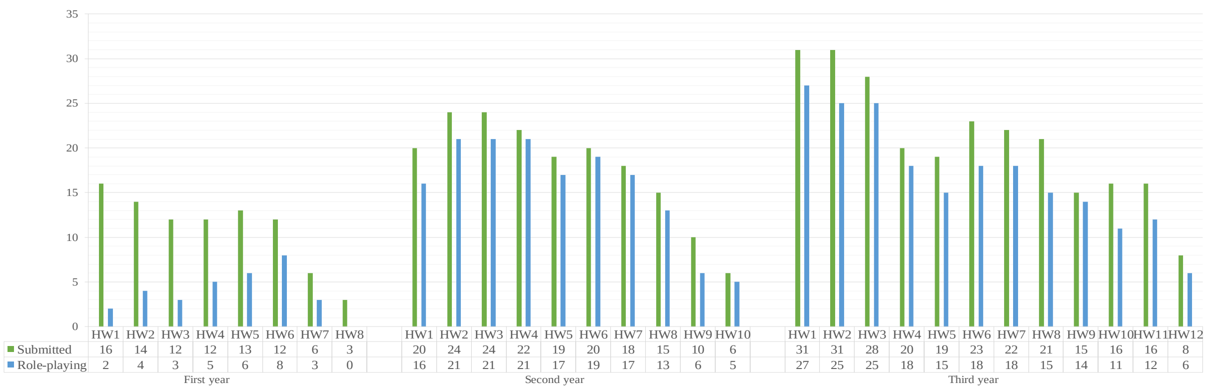

Figure 7. Number of Homework completed and role-playing

Table 6. Basic data about students' groups forum discussions

	First year	Second year	Third year
Total number of messages	42	97	81
Total number of student messages (N and %)	35 (83.3%)	92 (94.8%)	63 (77.8%)
Total number of teacher messages (N and %)	7 (16.7%)	5 (5.2%)	18 (22.2%)
Messages containing SRL indicators (N and %)	16 (38.1%)	35 (36.1%)	29 (35.8%)
Total number of SRL indicators	21	42	38
Average number of indicators per SRL-related message	1.3	1.2	1.3
Kappa value (k)	0.92	0.91	0.89

Table 7 shows the breakdown for SRL-related expressions detected by the two coders with respect to the six SRL-indicators presented in Table 2. Concurrence on these figures was gained following comparison and discussion between the two coders regarding the selected expressions within the messages (*k* values for each year are presented in Table 6). More detailed examination reveals that out of the total number of SRL indicators detected by the coders (N = 101) within the messages, 28.7% were related to “help seeking” (n = 29), 18.8% to “self-evaluation” (n = 19), 16.8% to “time management” (n = 17), 14.9% to “self-motivation” (n = 15), 10.9% to “knowledge activation” (n = 11), and 9.9% to “effort investment” (n = 10).

Table 7. SRL indicators detected by the coders within student group forum discussions

	First year	Second year	Third year	Total
[Forethought] Self-motivation	4	6	5	15
[Forethought] Knowledge activation	2	5	4	11
[Performance] Time management	3	8	6	17
[Performance] Help seeking	6	11	12	29
[Performance] Effort investment	2	5	3	10
[Self-reflection] Self-evaluation	4	7	8	19
Total	21	42	38	101

Table 8 shows basic data from analysis of the interviews regarding the number of expressions containing SRL indicators coded by the two coders. Once again, concordance was gained following comparison and discussion between the two coders (*k* values for each interview are presented in Table 8). Table 9 shows the breakdown of SRL-related expressions detected by the two coders with respect to the six SRL-indicators presented in Table 2. Once again, concordance was gained following comparison and discussion between the two coders (*k* values for each interview are presented in Table 8). More detailed examination reveals that out of the total number of SRL indicators detected by the coders (N = 17) within the interviews, 24% was related to “help seeking” (n = 4), 18% to “time management” (n = 3), 18% to “effort investment” (n = 3), 18% to “self-evaluation” (n = 3), 12% to “self-motivation” (n = 2), and 12% to “knowledge activation” (n = 2).

Table 8. Basic data from the semi-structured interviews

	Interview 1	Interview 2
Expressions containing SRL indicators	5	7
Total number of SRL indicators	8	9
Average number of indicators per SRL-related expression	1.6	1.3
Kappa value (*k*)	0.89	0.92

Table 9. SRL indicators detected by the coders within interviews

	Interview 1	Interview 2	Total
[Forethought] Self-motivation	1	1	2
[Forethought] Knowledge activation	1	1	2
[Performance] Time management	1	2	3
[Performance] Help seeking	2	2	4
[Performance] Effort investment	1	2	3
[Self-reflection] Self-evaluation	2	1	3
Total	8	9	17

Discussion and conclusions

Recently, the implementation of web-enhanced active learning in the context of Engineering Education has been gaining increasing attention from scholars. This approach has proven to be particularly effective in providing engineering students with suitable flexibility and contextualization for acquiring professional knowledge. Nonetheless, several studies have recommended that appropriate pedagogical guidance should be provided within such flexible learning settings. With the aim of promoting active learning and SRL in a supervised manner, in this study, a web-enhanced active learning approach was developed and tested. This implemented an SRL-based strategy to support students in managing their own learning pace and in monitoring their effort investment and performance, as well as offering support for decision making about the strategies they adopt to seek help and information. In order to evaluate the proposed approach, a three-year quasi-experimental study was employed in the context of an undergraduate Automatic Control course. In the following, the research questions presented at the beginning of the paper are discussed. It should be noted that RQ.1a and RQ.1b are discussed together for convenience.

SRL - Promotion online (RQ.1a) and measurement (RQ.1b). The results of this study show that the proposed approach significantly benefited the students in terms of promoting and developing SRL strategies. Analysis of the ex-ante survey and the ex-post survey reveals that significant effects were achieved regarding several aspects of SRL, namely self-motivation, time-management, help seeking and self-evaluation. However, it should be noted that no significant effects were generated regarding prior knowledge activation and effort investment. These results were confirmed by analysis of the student group forum discussions, where results align perfectly with those from the surveys: self-motivation, time-management, help seeking, and self-evaluation were the SRL indicators most evident within the forum discussion messages. Analysis of the interview results show that the SRL factors most significantly effected (in terms of teachers' expectations and observations) were, once again, self-motivation, time-management, help seeking, and self-evaluation; however, the teachers also considered that prior knowledge activation and effort investment were also effected. Analysis of the supervised learning activities (which was, as already stated, limited to the Homework activities) clearly showed that the number of the students participating in the Homework activities decreased over time in the same course: as curricular activities comprise various courses running in parallel, effort investment may have been affected. Moreover, the interested and motivated students seemed to have regulated the workload for accomplishing a personal objective - i.e., completing at least half of the Homework assigned to obtain a benefit in terms of formative assessment, while optimizing their resources in terms of time management and effort investment. The Homework activity probably helped the students in monitoring their time use and changing/renegotiating tasks. Therefore, we conclude that engineering students can improve their awareness of self-regulation when learning under the web-enhanced active learning approach, with respect to three areas for regulation:

- cognition, regarding complex problem solving (the capacity to deal with complex problems, finding connections and relations among concepts) and activation of reflective learning processes;
- motivation, regarding self-motivation (towards the subject); and
- behavior, regarding autonomy (ability to perform both individual and collaborative work), time management, and effort investment (in the course activity).

As far as evaluation and measurement of SRL development online, the quali-quantitative analysis adopted for the evaluation was in some ways innovative compared to what is reported in the literature concerning Control Engineering Education. The effectiveness of this approach can be measured by means of the narrative that the qualitative data (collected through thematic analysis of student group forum discussions and teacher interviews) offered in terms of keys for the interpretation of quantitative data (collected through self-reported student surveys and tracking of online activities). The data thus obtained can be read in an interrelated way to obtain - at a higher and more comprehensive level of detail - information on the triggered SRL dynamics, which then become observable and usable for a more authentic evaluation by the different stakeholders involved in the learning process.

SRL – Instructional representation (RQ.2). With respect to the implementation framework, the approach confirmed the effectiveness of the specific design strategy to implement SRL features in a web-enhanced active learning setting. It was important to deploy the course and, more in general, the learning activities within a learning environment capable of supporting flexible course design. Judging by the level of student satisfaction in the online environment, Moodle appeared to offer sufficient flexibility for the purpose. Moreover, in line with what is suggested by the reviewed literature, the online component was fundamental for providing students with a "walled garden" where they could nurture their own learning strategies, or familiarize with the new ones proposed, by means of implicit and explicit SRL prompts. The online environment proved to be effective in supporting the team of teachers in the implementation of multiple learning activities, each related to the appropriate area of the subject. In particular, the approach was effective in boosting some aspects of students' professional training; the declarative and procedural aspects of the knowledge domain could be dealt with by means of appropriately designed learning materials and self-assessment, while the contextual aspects of the knowledge were handled by means of supervised learning activities, some of which were formal tasks (i.e., Homework), while others were non-formal tasks (i.e., Resource Hunting). It should be noted that the proposed semi-structured tasks attracted less student participation compared to the more formal and structured tasks. This is a point to ponder more thoroughly so as to determine whether the incentive to carry them out should be strengthened or not. Finally, the encouraging initial results from evaluation of the approach might have broader implications for Engineering Higher Education in terms of seeking flexible learning models for integrating SRL into actual learning process within a formal curriculum.

There is one significant limitation to this study that should be noted, namely that related to student learning and measurement of the actual evidence of student achievement. As student achievement in mastering the requisite knowledge and skills should be considered the most relevant criterion in the learning process, students' ability to self-regulate their learning process should be considered important as this is instrumental in achieving such mastery. Discussion of this point, however, falls outside the scope of this work. This could be done, for example, by tracking more data from the actual student learning activities, such as the results of the self-assessment tests, and analyzing them with respect to meaningful SRL factors. In order to make the study findings generalizable to other engineering courses, it is suggested that future studies explore such scenario by adopting the evaluation method proposed in this study.

Acknowledgements

Professor Tommaso Leo, passed away on June 16, 2014, aged 70. He received the M.S. degree in electronic engineering from the Università La Sapienza, Rome, Italy, in 1968, where he was in touch with the prestigious school of Automatic Control held by prof. Antonio Ruberti. Since 1981, he was a Full Professor of Automatic Control with the Faculty of Engineering, Università Politecnica delle Marche, Ancona, Italy. With the same University, he was Director of the Department of Electronic and Automation from 1982 to 1988, Dean of Engineering Faculty from 1990 to 1996, Director of the Department of Information Engineering (formerly Department of Informatics, Management and Automation Engineering) from 2005 to 2011. From 2003 to 2013, he was rector's delegate for e-learning. He was chair of research programs and projects in robotics, automation, human movement analysis and e-learning. In the same research fields, Prof. Leo was author and co-author of more than 250 scientific papers, editor of scientific books and of special issues of International Scientific Journals. He was IEEE senior member. The life of Professor Leo was dedicated to science, education and engineering. His attention to teaching and to the students' needs was a key feature that has distinguished his teaching activity and that has seen him very active in technology enhanced learning. Prof. Leo had made significant intellectual contributions to the study presented in this manuscript and had been involved in the initial stages of its preparation.

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