Received 19 July 2018
Revised 11 January 2019
Accepted 8 March 2019

Reengineering engineering education at the University of los Andes

The REDINGE2 pilot project

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Abstract

Purpose – The REDINGE2 – Reengineering Engineering Teaching, version 2 – project seeks to transform engineering education practices at the University of los Andes (UNIANDES) by using technology-based active learning strategies in courses from different disciplines that are to be reformed using a Big-ideas approach. Studies from this two-year project (2017-2018) seek to solve three main questions: What changes in engineering teaching conceptions, methods, tools and practices could be generated by reengineering courses using a Big-ideas approach? What changes in key conditions of learning environments have the students perceived in courses that use a Big-ideas approach? What lessons can be derived from the initial studies of REDINGE2's pilot experiences?

Design/methodology/approach – The REDINGE2 project was conceived as a technology-based educational transformation initiative. It is the Faculty of Engineering at UNIANDES' explicit intention to move engineering teaching from being content-focused to being big-ideas focused. It also wants to migrate from teacher-centered teaching strategies to student- and group-centered approaches. Additionally, this project intends to enrich engineering education ecologies with digital resources by integrating experiential, flexible and collaborative digital learning environments with traditional classroom/workshop/library/home/work learning settings. To promote this organic change, the project implemented a facilitation-from-the side strategy, which redesigned 14 engineering courses: each was given a two-year grant from the Office of the Dean of Engineering to rethink teaching practices and redesign the course. A cybernetic evaluation system was embedded in the life cycle of the transformation process that could support decision-making through each of the project's stages (Stufflebeam, 1971). Questions of interest in this study are provided with information using triangulation of data at different times during each course's redesign process.

Findings – After a year and half of the two-year REDINGE2 project (2017-2018), it is possible to say the following three research questions are fully solved. Concerning Question #1: What changes in engineering teaching conceptions, methods, tools and practices contribute to reengineering courses when using a Big-ideas approach? Participating teaching staff have demonstrated changes in their teaching conceptions, methods and resources, which can be attributed to their exposure to active-learning strategies supported by digital technologies. In fact, each one has redesigned and pilot tested at least one restructured learning unit for one of their courses according to the proposed Big-ideas approach; in addition, most admit to already having adjusted their teaching practices by changing their mindset regarding learning and how to promote it. Concerning Question #2: What changes in key conditions of learning environments have the students perceived in courses that have been redesigned using a Big-ideas approach? Data collected from students and participating staff members, both before the redesign and throughout this process, have provided teachers and students with feedback concerning perceived changes in learning environments. This has had positive results and provided opportunities for improvement. Concerning Question #3: What lessons can be derived from REDINGE2's pilot experiences? Lessons from this project are multi-dimensional and there are organizational, pedagogic, technological and cultural considerations. A decalogue of critical success factors was established, which considered the things that must go right to successfully accomplish proposed educational transformations.

Kybernetes
Vol. 48 No. 7, 2019
pp. 1478-1499

0368-492X
DOI 10.1108/K-07-2018-0384

Research limitations/implications – This study is a good case of educational transformations in engineering teaching. No generalizations should be made, but it shows that similar processes of planned change can be made in tertiary science, math, engineering and technology (SMET) education.

Practical implications – The lessons learned from this experience are very valuable for higher education decision-makers who want to innovate by using learning ecologies in their institutions. In addition, theoretical considerations that illuminate the innovation process become very useful to help provide a foundation to similar interventions.

Originality/value – A non-conventional approach to integrate digital technologies in higher education teaching is the most significant contribution this experience has made. Its focus has been to transform educational practices with pedagogically sound uses of digital technologies instead of just integrating technologies in current SMET teaching practices. Facilitation-from-the-side and embedded cybernetic evaluation through the transformation process are key ideas that add value to organic change processes.

Keywords Engineering education, Active learning strategies, Course-redesign, Cybernetic program evaluation, Digital technologies for education, Educational transformations, Student-centered teaching, Group-centered teaching, Technology-based educational innovations, Course redesign with facilitation-from-the-side, Technology-based educational transformations, Idea-based course redesign, Cybernetic project evaluation

Paper type Case study

Introduction

Ever since it was founded in 1948, the School of Engineering at the University of los Andes (UNIANDES) has been a national leader training engineers and researchers who are at the forefront of the discipline. Its website states that its undergraduate, masters and doctoral programs are based on the best international practices, which focus not only on the acquisition of technological competencies, but also on the development of soft skills such as communication, leadership, management, and interaction with interdisciplinary teams (UNIANDES - Facultad de Ingeniería, 2017). This strategic declaration is aligned with Objective 1.4 of the University's 2016-2020 Development Plan, as it declares that the institution will continue:

> [. . .] to have academic programs based on the development of competencies that are evaluated comprehensively and systematically against international standards and criteria such as quality, innovation, flexibility, interdisciplinarity, internationalization and sustainability (UNIANDES, 2015).

In this context, the dean of the School of Engineering stated in a recent editorial about hybrid learning environments (Reyes, 2018, p. 5) that flipped classroom, active pedagogies, authentic evaluations, intensive use of appropriate technologies, and physical learning spaces that allow team work in classroom settings seek to align the structure of the university, pedagogic teaching strategies, and students' expectations. He uses a common expression that reflects internal tensions in higher education: universities have nineteenth century structures, twentieth century faculty members and twenty-first century students. Because of this reality, the Dean's Office has undertaken several different innovative programs: REDINGE2 being one.

The REDINGE2 – Reengineering Engineering Teaching, version 2 – project seeks to transform engineering education practices at the UNIANDES by using technology-based active learning strategies in courses from the different disciplines that are to be reformed using a *Big-ideas* approach. The REDINGE1 project (2015-2016) with three courses served as a pilot and important lessons were learnt (Galvis *et al.*, 2017). These lessons planted the seed for a second pilot – REDINGE2 – with 14 courses from all engineering disciplines and all curricular levels. The first semester was devoted to course analysis and design (macro level) using a *Big-ideas* approach (Galvis and Pedraza, 2012), the second to learning unit design (micro level) and the third to curriculum materials and learning environments development with evidence-based adjustments. This paper was written before the fourth and final semester of the REDINGE2 project: 8 of 14 courses have already been calibrated and will be pilot tested while the remaining six will be calibrated based on findings from proof-of-concept experiences and then pilot-tested in 2019-1. A CIPP – context, input, process, product – cybernetic evaluation model (Stufflebeam, 1971) was embedded in the process, and it helped to provide valid and opportune information to make decisions on each one of the fourteen courses that were being redesigned.

Full implementation of all redesigned courses during 2018-2 and 2019-1, with the appropriate data collection, will provide the means to carry out future effect and impact studies on learner performance and soft skills.

Context: educational needs in engineering and digital technologies

As mentioned by Crawley *et al.* in their writing about "educating engineers for 2020 and beyond," Charles M Vest, former President of MIT and, later, of the US National Academy of Engineering, mentions:

> [engineering] students must learn how to merge the physical, life, and information sciences at nano-, micro-, and macro-scales, embrace professional ethics and social responsibility, be creative and innovative, and write and communicate well (cited in Crawley *et al.*, 2014, p. v).

Vest also states:

> [engineering] students should be prepared to live and work as global citizens and understand how engineers contribute to society. They must develop a basic understanding of business processes, be adept at product development and high-quality manufacturing, and know how to conceive, design, implement, and operate complex engineering systems. They must increasingly do this within a framework of sustainable development, and be prepared to live and work as global citizens (cited in Crawley *et al.*, 2014, p. v).

The same author also indicates:

> [. . .] we cannot know exactly what they [students] should be taught, we focus on the environment and context in which they learn, and the forces, ideas, inspirations, and empowering authentic situations to which they are exposed (Vest cited in Crawley *et al.*, 2014, p. v).

He agrees with Murray Gell-Mann, winner of Nobel Prize in Physics in 1929, who often says, "We need to move from the sage on the stage to the guide on the side" (Gell-Man cited by Vest cited in Crawley *et al.*, 2014, p. vi). Key educational ideas, such as studio teaching, team projects, open-ended problem solving, experiential learning and engagement in research should be integral elements of engineering education.

The above vision contrasts with some traditional engineering teaching practices where professors in the Faculty teach as they were taught. This reinforces the idea that their role is to transfer relevant mental models to help students understand and solve problems with engineering methods and tools. There are, however, signs of planned and unplanned changes in engineering education as both universities and many other providers of secondary and/or tertiary education are focused on developing competences and widening access to formal and informal SMET – science, math, engineering and technology – education.

When discussing *reengineering engineering education*, Towner states:

> [. . .] today, the antithesis of the mass production approach employed by higher education is emerging. Students have more options regarding the delivery method of education material than ever before. In addition to traditional face-to-face lectures, blended, synchronous and asynchronous online courses, massive open online courses (MOOCs), and competency-based courses are some of the more recent teaching methods available (Towner, 2017, p. 35).

The use of digital technology for teaching is apparent in all these opportunities, and a variety of educational and technological innovation strategies are available for schools of engineering and their teaching staff to consider. Key educational ideas, such as paying attention to learning styles (Entwistle, 2001); reflection as a teaching and learning method (Durgahee, 1998); implementing authentic-situation collaborative project- problem- and case-based learning (Mills and Treaagust, 2003; Coll *et al.*, 2004; Peralta Caballero and Diaz-Barriga, 2010); getting the best from face-to-face and virtual education modalities in hybrid modality (Garrison and Kanuka, 2004; Osorio Gómez and Duart, 2012; UNIANDES - Facultad de Ingeniería, 2018); facilitating learning processes from-the-side (Collison *et al.*, 2002; Badia, 2006); making good use of autonomous-time and class-time by implementing flipped classroom ideas (ITESM, 2014; Baytiyeh and Naja, 2017; Galvis *et al.*, 2018); conducting interactive face-to-face classes, even with large groups (Graham *et al.*, 2007; Heaslip *et al.*, 2014; Campbell and Monk, 2015); learning anytime, anywhere (Salinas Ibáñez, 2003; Gros, 2016); and blending space, time, pedagogies, media, modalities, and leaning experiences (Singh, 2003; Galvis, 2017; Galvis, 2018b) are all possible when there is sound use of digital technologies for teaching (Bates, 2015; Onrubia, 2016; Galvis, 2018a; Zea, 2018).

REDINGE2: a technology-based educational transformation initiative

The REDINGE2 project was conceived as a technology-based educational transformation initiative. As Salinas mentions:

> [. . .] we can consider innovation as a creative form of selection, organization and utilization of human and material resources. This new form results in the achievement of previously marked objectives. We are therefore talking about changes that produce improvement, changes that respond to a process planned, deliberative, systematized and intentional, not of simple novelties, of momentary changes or of visionary proposals (Salinas, 2004, p. 5).

The REDINGE2 project has the explicit intention of moving engineering teaching from being content-focused [teaching relevant subject matter] to *Big-ideas* focused [teaching for understanding fundamental course concepts]. It wants to migrate from teacher-centered teaching strategies to student and group centered approaches, and, additionally, this project intends to enrich engineering education ecologies with digital resources, integrating experiential, flexible and collaborative digital learning environments, and traditional classroom/workshop/library/home/work learning settings.

Ideas taken from Sáez Vacas, 1997; Coll *et al.*, 2007; Garcés-Prettel *et al.*, 2014, were instrumental to achieve this goal and to create the appropriate organizational, technological, and pedagogical framework. When REDINGE2 was launched and the faculty members applied to participate in the program, there was a clear organization-individual alignment that allowed technology in education to become a potential amplifier of core ideas, as is detailed in UNIANDES' mission. In fact, the 2016-2020 Comprehensive Development Plan states that the university:

> [. . .] strives for academic excellence and gives its students a critical and ethical education that will solidify in them an awareness of their social and civil responsibilities as well as a commitment to

> their country. It [UNIANDES] has students who, within an environment that promotes comprehensive, interdisciplinary, and flexible teaching are the principal agent in their own education (UNIANDES, 2015, p. 6).

In addition, the Faculty Handbook acknowledges "teaching research, development, and innovation as academic output at any [academic] unit" (UNIANDES -, Secretaría General, 2015, p. 19).

Big-ideas design approach

Big-ideas: A nontraditional course design approach for *teaching*, focused on understanding fundamental course concepts, was adopted as a framework for redesigning engineering courses. "Experiences in different higher education domains have shown that organizing teaching around a small number of *Big-ideas* is important in teaching for understanding" (Mitchell *et al.*, 2017, p. 596). As this approach was implemented, "the emphasis in course design is now on promoting key understandings, core competencies, and an understanding of connections between different fields" (Rowland *et al.*, 2011, p. 267). According to Hansen (2011), course design usually focuses on teaching and aligning the content of the course with the needs it must satisfy. In contrast, when designing courses focused on learning, after clarifying the needs that the course must attend, everything that the student should learn to achieve is detailed in the objectives, and a plan to promote deep understanding of concepts in a non-linear way is designed. The students are guided by essential questions the answers to which must be found in groups through experimentation with content rather than by simply memorizing concepts. The distinction between the *logic of teaching* and the *logic of learning* is very important, which aids understanding (McTighe and Wiggins, 2004; Wiggins and McTighe, 2005) and can be discerned with the help of what is known as the "backward design model" (McTighe and Wiggins, 2004 p. 290). The methods and design tools detailed in the above paragraphs were implemented in the REDINGE2 project design by following good practices derived from prior experiences in the USA and Colombia (Galvis and Pedraza, 2012).

Active learning ideas behind REDINGE2

Gell-Mann'*s* proposal of moving [the instructor] from being the sage on the stage to the guide on the side is intrinsically related to the idea of evolving teaching from a traditional [teacher centered approach] to active learning [student and group centered]. In this shift, the act of learning moves "from a culture based on knowledge transmission centered on the teacher to a culture of appropriation centered on the student" (Raucent *et al.*, 2005 p. 27). A recent guest editorial on active learning states that despite consistent results showing that, "on average, engaging students through active strategies enhances learning" (Streveler and Menekse, 2017, p.189), active learning is not necessarily a panacea or a blanket remedy for all instructional inadequacies. These authors suggest that teachers should design instruction that matches the kinds of activities with the importance of outcomes to be achieved. In the REDINGE2 project, learning strategies are designed after there is a clear understanding of the why, for whom, what to learn, and how to demonstrate learning. This is a comprehensive and coherent framework to help select learning strategies and technologies that aid students appropriate, share, and demonstrate knowledge.

Self-regulated learning (SRL)

Self-regulated learning (SRL) was another important concept explored and integrated as a conceptual reference for course design in the REDINGE2 project. Studies by Boekaerts, 1997; Pintrich, 1999; Zimmerman and Schunk, 2008; Ambrose *et al.*, 2010 have illuminated this component that relates to course redesign. SRL research provides evidence-based recommendations on how to teach based on how we learn. This has great synergy with idea-based design, which uses the logic of learning to create learning environments that foster conceptual understanding. Research findings from Ambrose *et al.* (2010) are organized around seven learning principles concerning the role of students' prior knowledge, motivation, and developmental level as well as opportunities for the student to practice, receive feedback, and learn to become a self-directed learner. These findings help to implement the learning for understanding ideas model proposed by McTighe and Wiggins, 2004; Wiggins and McTighe, 2005; Erickson, 2007.

Key conditions of technology-based learning environments assessment

The previously-mentioned pedagogical ideas and the variety of techno-pedagogical opportunities available to implement technology-based active learning strategies helped to create and pilot an instrument to assess key conditions of learning environments – KCLE – (UNIANDES – CONECTATE, 2017b), see Figure 1. The KCLE survey, which assesses six categories that research technology-based learning environments, has proved to be very important. The six categories are: technological tools; course organization; contents; activities; interaction; and evaluation mechanisms (Galvis, 1992; Jonassen and Rohrer-Murphy, 1999; Collis and Margaryan, 2004; Chen *et al.*, 2008; Osorio Gómez and Duart, 2012; Bates, 2015).

Methodology

Multidimensional aspects are considered part of the methodology to implement and learn from this project. Organizational elements were examined to set up the scenario and to run the project, and they were of particular use when fostering effective participation from the different actors. Pedagogical, technological, and logistical considerations were taken into account to define and implement the intervention strategy. Cybernetic considerations framed the design of the assessment and project's evaluation system.

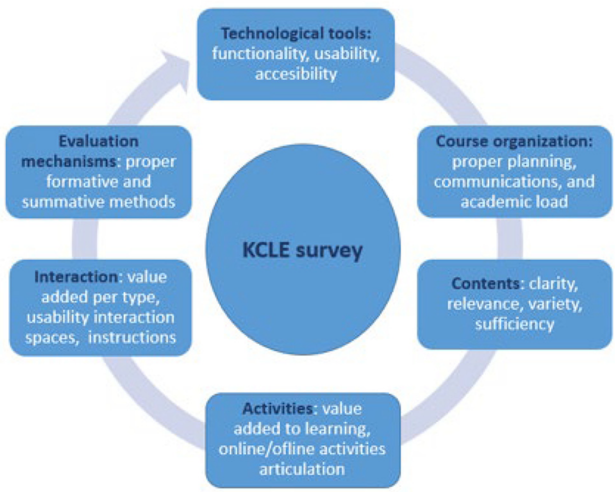

Figure 1. Variables per component of the KCLE survey instrument

Participants and facilitation-from-the-side

Fourteen staff members from all departments of the School of Engineering volunteered, and their academic load was reduced by either a third or a quarter over a two-year period. They were also given access to internal and external resources that helped them take on the transformation challenge proposed by the dean. A coaching strategy was designed and implemented by CONECTA-TE, the Center for Innovation in Education and Technology, part of the School of Education at UNIANDES. The Center aims to help innovators rethink and reshape their teaching by (1) promoting students to become the principal agents in their own education, (2) establishing learning ecologies that integrate both local and global learning opportunities with flexible and collaborative technology-supported learning environments (UNIANDES - CONECTA-TE, 2017a). Multidisciplinary advisory teams were created by CONECTA-TE as coaching cells that could facilitate-from-the-side (Collison *et al.*, 2002; Badia, 2006) each course redesign. Each advisory cell worked with seven courses-to-be-redesigned, and they included pedagogic and technologic consultants as core members. Software, multimedia, and web-developers also participated when needed as did educational program evaluators.

Intervention design and embedded evaluation strategy

Using the above theoretical and organizational framework, the REDINGE2 project was divided into five time-related stages: content analysis; course level redesign; learning-units redesign; learning environments creation with pilot testing and adjustment; and course implementation and evaluation. Figure 2 shows the project timeline and value chain activities in each one of the project life cycle stages. Innovators interacted for around four hours per week with the multidisciplinary team assigned to coach them, and they worked by themselves for another six hours per week. Both multidisciplinary coaching teams simultaneously worked on seven courses-to-be-redesigned, working together as a cell. This allowed each individual advisor to balance their internal weekly work load depending on the rhythm of each course redesign. All innovator faculty members belonged to the School of Engineering, but their courses were part of different programs or different program levels. These courses served a variety of students who were in different academic years of study and who had a variety of personal interests. Some redesigned courses had a large number of students and several sections, which was a reason to standardize exams and/or rubrics. For large courses, it was possible to make comparisons between sections that had been

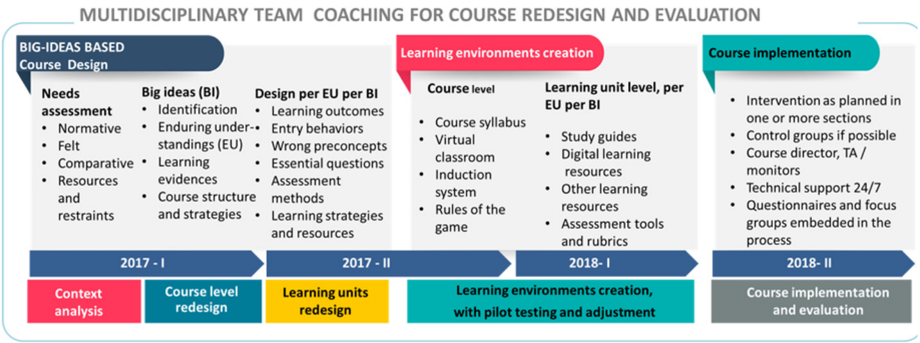

Figure 2.
REDINGE2 project timeline and value chain

Source: Authors

redesigned and those that had not; however, for smaller sections, it was only possible to make comparisons between different years.

The proposed evaluation model, CIPP, shown in Figure 3 was implemented in parallel with the project's value chain.

During REDINGE2's first semester (2017-1), two complementary types of activities were conducted:

(1) An educational needs assessment was undertaken for each of the fourteen courses by consulting normative, felt, and comparative needs as well as by identifying applicable resources and restraints. Based on findings, the *Big-ideas* approach was applied to the curricular redesign of the courses. The macro structure for each course, in terms of fundamental concepts, assessment methods, and general learning strategies was defined.

(2) Baseline information was collected from 2017-1 course implementation given that there had been no interventions made in any of the courses-to-be-redesigned. Faculty members were observed in class by pedagogic advisors, and interviewed about their learning and teaching concepts and practices. An SRL scale was included in students' course feedback survey as a reference point to orientate course activities design. A key conditions of learning environments (KCLE) survey was given to students from each course to be redesigned. Two other elements derived from input evaluation were included in the baseline: students' characterization through data mining from institutional data repository, and benchmarking of relevant resources, practices, and trends in similar courses at leading universities. Sharing the above information with teachers nurtured reflection on their scholarship of teaching and allowed analysis of opportunities to transform some practices by using technology-based active pedagogy.

During the second semester in which REDINGE2 was implemented (2017-2) each of the learning units per course was designed following a *Big-ideas* approach (Galvis and Pedraza, 2012), as follows:

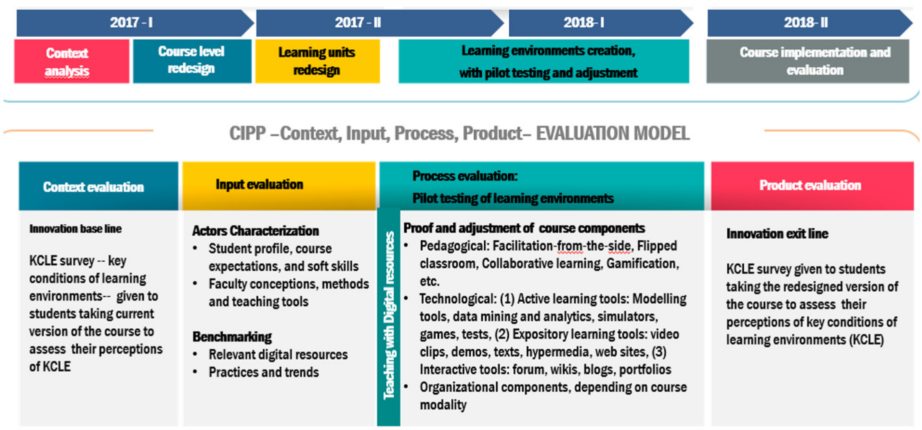

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Figure 3.
CIPP evaluation model, embedded with REDINGE2 project value chain activities

- Design component #1: *What to learn*. Learning outcomes (final learning stages) were established for each one of the fundamental concepts (*big-ideas*) that should last in the long-term (enduring understandings). Expected entry behaviors and potential wrong pre-concepts (initial learning stages) were identified. Conceptual bridges were created by using essential questions that conceptually helped moving forward from the initial to the final learning stages; answering these interrogations per *big-idea* through technology-based active learning methods should help students fill their learning gaps.
- Design component #2: *How to demonstrate understandings*. Productive learning outcomes were assessed with authentic tasks (real life related) through problems, projects, or cases. These challenges were accompanied with rubrics (assessment criteria) because their use promotes self-control through the problem-based learning process. Conventional tests were not discarded because reproductive learning outcomes can be mastered through practice with immediate and differential technology-based feedback.
- Design component #3: *how to promote learning*. Technology-based learning strategies to encourage active learning were defined while taking into consideration the level and nature of the desired learning outcomes. A range of opportunities were considered because active learning strategies can be implemented with a wealth of digital technologies. SRL principles became very instrumental in this process since alignment of activities with learning outcomes and expected learning evidences was paramount.

At the end of the second semester (2017-2) and during the third (2018-1):

- Digital learning resources were either produced, adapted, or adopted as soon as each learning unit was designed. This tactic allowed for unit-level learning environments to be developed and field tested in small cycles while applying agile digital resource production methods.
- Process evaluation was embedded through the design and production phases (Figure 4). Focus groups with students testing resources or learning units helped to debug and adjust these elements. Formative assessment reports were discussed with innovators and adjustments were made and decisions were taken.
- The KCLE survey was given to students in courses were learning units had been field tested. This gave the faculty feedback on the six components of redesigned learning environments. Of the 14 courses, 8 had minor adjustments to be made; the rest had either curriculum materials production or content/pedagogy challenges to be met, so a calibration semester was introduced before we moved forward into implementation and summative evaluation.

When this study was written at the end of the 2018-1 academic period, the fourth semester of the REDINGE2 project had not been conducted. During 2018-2, a full course implementation and product evaluation will be conducted for eight out of the fourteen courses, while the six remaining courses will be calibrated after adjustments.

Findings from the first year and a half of the REDINGE2 project

The REDINGE2 project has been a chance to rethink engineering education learning ecologies and their foundations. It builds on engineering instructors' previous concepts, methods, and tools as well as on opportunities to transform these with technology-based

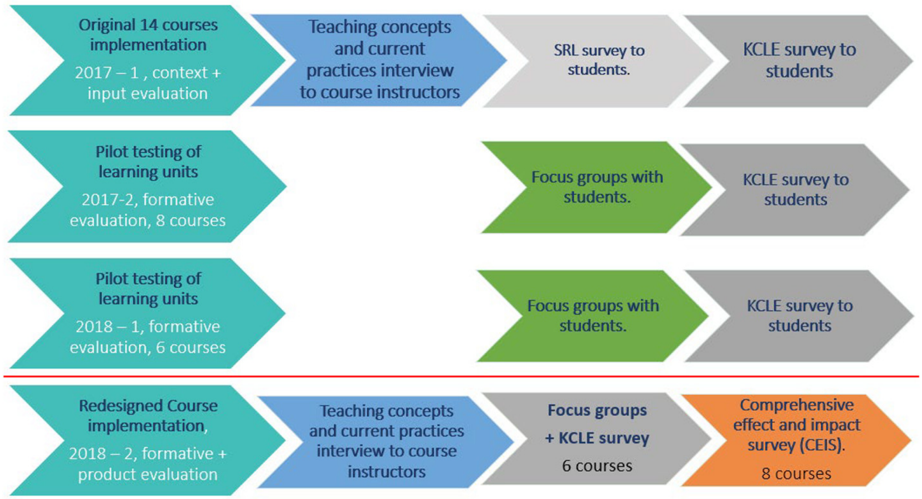

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Figure 4. Assessment-based data collection during the REDINGE2 project

active learning strategies. It uses a *Big-ideas* approach to organize the knowledge, skills, and attitudes to be acquired per course. The following three research questions prompted the initial studies regarding this innovation process:

RQ1. What changes in engineering teaching conceptions, methods, tools and practices contribute to reengineering courses when using a Big-ideas approach?

To solve this question, we reviewed changes in course design structures and looked at both pedagogical and technological components and their emphasis on promoting either disciplinary (course-related knowledge) and/or soft skills (collaborative work and/or self-regulated learning). Figure 5 synthesizes our findings. It is interesting to notice that building, sharing, and transmitting disciplinary knowledge has been the predominant focus of the fourteen courses before and after course transformation both from the pedagogical

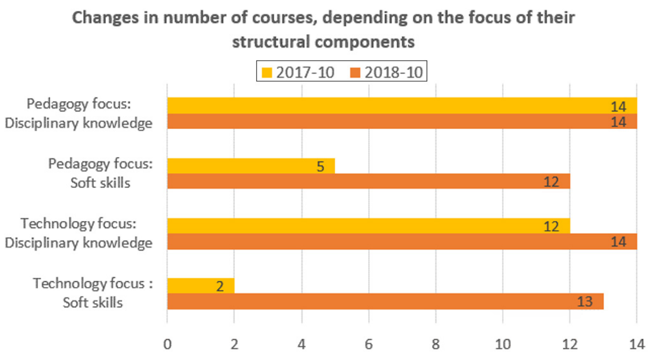

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Figure 5. Course design structural transformation after 1.5 years of REDINGE2 project

and technological perspectives. A significant increase in the number of courses that intentionally promote soft-skill development both from the pedagogical and technological components of course designs throughout the year and a half during which innovations have been made can be clearly seen.

The above findings can be better understood by looking at changes in the number of courses that use a variety of pedagogic strategies and different assessment types and tools. These promote different learning objectives and include diverse types of digital resources according to their role per type of media as will be detailed later. The Figure 6 and Tables I, II, III and IV present our findings.

Figure 6 shows a clear reduction of lecturing in class-sessions and an increase in other active-learning pedagogic strategies. Four challenge-solving related pedagogic approaches achieve a key role (team-, project-, problem- and case-based learning) in the majority of redesigned courses. In addition, inverted classroom strategies (also called flipped classroom) become predominant in twelve of the fourteen courses: this transformation implies that students build, adopt or adapt digital learning resources outside the classroom. Additionally, two courses implement blended learning, which implies a reduction in face-to-face activities by more than 30 per cent and less than 70 per cent of all learning events.

Table I shows that throughout the year and a half there has been an increase in the number of courses using student and group-centered learning activities. By using Bloom's taxonomy of learning objectives (Anderson *et al.*, 2001), Table I shows that there has also been an important increase in the level of learning outcomes, which is perhaps because of the use of authentic performance challenges in enduring understanding per big-idea.

Table II shows that conventional learning assessment techniques keep their position, and a variety of new methods have become part of the assessment process, which is in alignment with a higher level of performance for the objectives.

Table III shows that diagnostic tests are applied for self-assessment and hetero-assessment. These instruments are administered technologically and build on items that belong to test data bases. Formative evaluation is increasingly practiced in all types of assessment, and is usually administered technologically. As can be seen in Table II,

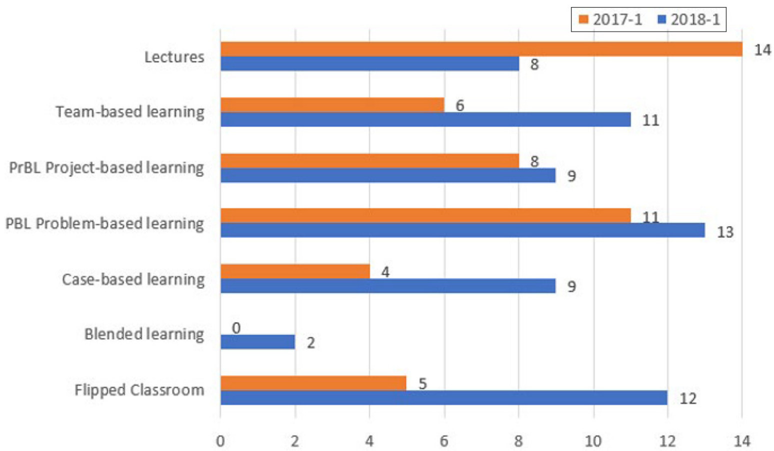

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Figure 6.
Changes in the number of courses using diverse pedagogic strategies

Table I. Number of courses per intended level of learning objectives and per type of learning activity

Learning activities	Semester	Intended level of learning objectives, according to Bloom's taxonomy						
		Knowledge	Comprehension	Application	Analysis	Evaluation	Creation	Total # of courses
Case study	2017-10		2	1	1			*4*
	2018-10		3	2	3	1		*9*
Lab workshops	2017-10		4	5				*9*
	2018-10		1	2	2	3	2	*10*
Class preparation	2017-10	6	1					*7*
	2018-10		9	2	1		2	*14*
Project development	2017-10		2	2	1	1	2	*8*
	2018-10			2		2	5	*9*
Simulations	2017-10	1		4			1	*6*
	2018-10			2	1	1	2	*6*
Authentic Problem solving	2017-10		5	5	1			*11*
	2018-10		2	2	5	3	1	*13*
Team work	2017-10			4	1	1		*6*
	2018-10		2	1		3	5	*11*

Source: Authors

Table II.
Number of courses using different assessment techniques

Assessment techniques	2017-1	2018-1
Problem-solving	12	14
Multiple-choice questions	14	14
Check lists	0	5
Likert-type scales	0	3
Learning journals	9	12
Case studies	3	12
Course projects	9	10
Debates	4	9
Learning portfolios	2	6
Conceptual maps	1	1
Rubrics	3	11
Total number of courses	*57*	*97*

Table III.
Number of courses using different assessment types per assessment role

Assessment type	Assessment role	Semester	# Courses
Self-assessment	Diagnostic	2018-1	1
	Formative	2017-1	3
		2018-1	14
Co-assessment	Formative	2017-1	1
		2018-1	5
	Summative	2017-1	3
		2018-1	5
Hetero-assessment	Diagnostic	2017-1	1
		2018-1	9
	Formative	2017-1	13
		2018-1	14
	Summative	2017-1	14
		2018-1	14

summative evaluation keeps its position, and, in many courses, it is not only limited to exams.

Table IV manifests that all types of media are used in redesigned courses, and there has been a significant increase in active and expositive media. This helps to understand that the shift in pedagogies from conventional to active and inverted is supported with these devices and that, because of their use, it is possible for instructors to "move from the sage on the stage to the guide on the side," as advocated by Gell-Mann (cited by Vest, cited in Crawley *et al.*, 2014, p. vi).

In summary, teaching staff who participated in the project have made changes in their teaching conceptions, methods, and resources that can be attributed to their exposure to active-learning strategies supported with digital technologies. All professors have redesigned and pilot tested at least one restructured learning unit for one of their courses based on the proposed *Big-ideas* approach. Also, most have already adjusted their teaching practices by making changes to their approach to learning and how to promote it.

The following videos present interesting teacher-testimonies, in Spanish. Teachers highlight how the Big-ideas approach helped them to focus on fundamental concepts instead of on contents; how flipped classroom strategies promoted significant motivation for independent study before classes and increased participation during class sessions; and how

Type of media	Role	Type of digital resource	# of courses/ semester 2017-10	2018-10
Interactive media (person-to-person intercommunication)	Collaboration	Blogs	1	1
		Surveys	2	3
		Forums		3
		Wikis		2
	Communication	e-mail/chat	10	13
		e-Forms	2	3
		Instant messaging	2	3
		Student response systems	5	6
Active media (person with digital system interaction)	Learning objects exploration	Drill and practice	2	4
		Serious games		3
		Simulators	3	3
		Assessment systems	2	9
		Learning management	3	13
		Customized software	2	4
		Interactive tools		8
		Knowledge maps		4
		eBooks		4
Expositive media (digital device-to-person information)	Content presentation	Infographics		10
		Presentations	10	13
		Digital repositories	11	8
		Tutorials		8
		Video clips		11

Source: Authors

Table IV. Number of courses per type of digital resource, per learning role and per type of media

project-oriented assessment allowed soft skills to be nurtured, in particular collaborative inquiry-based learning around significant challenges. Both testimonies help to communicate what has been the effect of participating in REDINGE2 project, and the professors reflect on innovative teaching and students¨ learning strategies.

In addition to the above indicators for change, it is important to highlight that the REDINGE2 project has been a catalyst for the increase in the number of course innovators: from the fourteen originally involved to sixty-eight. Eleven more teachers have since joined the effort as they either teach other sections of the same course and have rethought their teaching, or their courses are closely related with those that have been redesigned and the sequence of courses have been aligned. Figure 7 also shows that graduate assistants and under-graduate monitors have joined the initiative. They have helped course innovators in curriculum material creation or debugging as well as implementing active learning methods in their classes.

RQ2. What changes in key conditions of learning environments have the students perceived in courses using a Big-ideas approach?

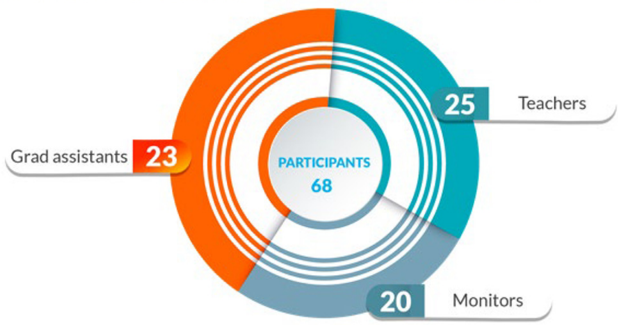
The previously-mentioned structural changes in course design implemented in the REDINGE2 project help understand major shifts in key ways that people learn. There has already been evidence of perceived effects based on the KCLE results, as can be seen in Figure 8. Using a 1 to 5 point-scale, the results show that there have been advances in all the variables that were measured using the KCLE surveys, and that

Source: https://youtu.be/DSS7Cbl10p0

Plate 1. Changes in teachers' teaching

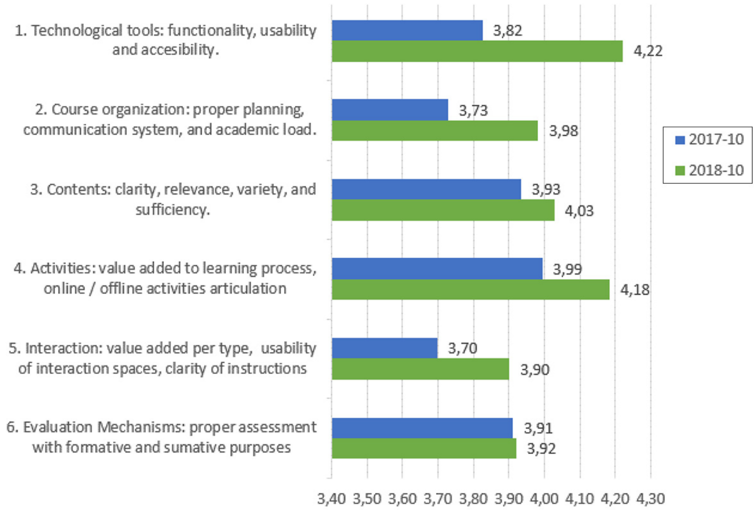
Source: https://youtu.be/4WEjjQ3Q0Gc

Plate 2. Changes in students' learning strategies



Source: Authors

Figure 7. Human capital involved in the REDINGE2 project



Source: Authors

Figure 8. Changes in key conditions of learning environments throughout the year-and-a-half course redesign

there is still room for improvement, particularly for variables measuring below 4.0. This improvement will be fostered in each one of the courses through reflective interaction with course innovators.

Surveys and focus groups with students allowed us to ascertain student perceptions about the techno-pedagogical course transformations. Discussion of student perceptions with each course redesign team were formative and allowed course components to be adjusted as needed. The following are the major conclusions:

- Students highlight the contribution made using technology for learning processes.
- They value the use of diverse resources to access pertinent, accurate and sufficient information.
- Students recognize that interaction between themselves as well as with teachers has improved.
- They identify the improvement of the evaluation and feedback processes, which informs them as to how tasks should be completed.
- Students point out that the redesigned course activities are interesting and motivating because they are authentic and close to professional work.
- They indicate that course-organization has improved, their academic load has become more balanced, there are more effective communication mechanisms, there is good activity-distribution, and an adjusted content-accessibility.

RQ3. What lessons can be derived from the initial studies of REDINGE2's pilot experiences?

Lessons from this project are multi-dimensional and include organizational, pedagogic, technological, evaluative, and cultural lessons. We have selected ten that we consider to be critical success factors (CSFs), that is, they are "key areas were things must go right to successfully achieve objectives and goals" (Rockart, 1979, p.82). These CSFs are important recommendations for future innovation experiences.

(1) Commitment from sponsors, participating instructors and coaching teams is a must. It provides the means to properly implement the proposal and helps to keep motivation high throughout the process.
(2) Alignment between the intention of the project, its pedagogical foundations, instructional methods, and digital tools provides important synergies. This makes possible the creation of new ecologies for learning that foster the use of "problemic" (problem-centered), experiential and reflective strategies for teaching and learning.
(3) Course stakeholders undertaking collaborative course redesign helps to generate solid products. Different perspectives and experiences help to create articulated, rich and complementary solutions. Participation of representative students in the redesign and assessment processes helps to fine-tune methods, messages and strategies.
(4) Understanding students' characteristics and their prior experiences and expectations allows for student-centered design to be undertaken. Each course redesign responds to needs assessment, but it is not enough; considering students' profile, prior knowledge (or lack of it), their expectations and motivations, helps building relevant learning experiences.
(5) Openness to criticism and gaining constructive feedback is not easy, but it is necessary. Each phase of the redesign and assessment process brings opportunities and evidence that support decision-making, beyond just individual ideas.
(6) Digital technologies should be devoted to materializing the project's pedagogic framework and the derived teaching strategies. This leverages technology-based active learning strategies and provides the means to promote a cultural change for teachers and students.
(7) Appropriate LMS platform set up is as important as powerful course redesign. This includes user friendly and consistent interfaces, intuitive digital classroom organization, versatile access to digital content, powerful collaboration and knowledge management tools, and diverse learning assessment devices with integration with the grading system.
(8) Stakeholders for each redesigned course play a key role institutionalizing the innovation. Each learning community should understand pedagogic ideas behind the redesign and feel comfortable using technologies that help to implement the proposed changes. Training and support are critical in this endeavor.
(9) Assessment and evaluation methods and tools ought to be embedded in the transformation process. This provides opportune and reliable information that supports decision-making through the life-cycle of a course's transformation.
(10) Opportune and careful socialization of assessment results makes a difference. It allows innovators and course stakeholders to reconsider design elements when necessary and gives them evidence-based feedback.

Conclusions

Findings from this pilot study show that participating teaching staff have demonstrated changes in their teaching conceptions, methods, and resources. This can be attributed to their exposure to active-learning strategies that are supported by digital technologies, as well as to coaching throughout the redesign process from Conecta-TE's advisory team. Learning ecologies have been transformed for active learning; this includes moving instructors and their assistants from the center to the side of the learning process, as well as providing pedagogically rich and technologically flexible digital resources for students to use (either individually or as study-group members). Qualitative research strategies have helped to establish students' perceptions about the key conditions of learning environments in each of the courses, and course redesigners have received feedback from them concerning different learning objects and strategies that have become part of each course. Based on evidence from the formative assessment, by the end of the first year-and-a-half of the REDINGE2 project (2017-1 to 2018-2), 8 of the 14 courses are ready for implementation and summative evaluation. The remaining six courses will go through this process in 2019-1.

REDINGE2 educational transformation project provides important lessons to be considered for future technology-based innovation experiences; a decalogue of critical success factors has been established and may help other course reformers when taking into the several factors that make the difference in technology-based educational innovations.

The project has provided rich and varied ways to enhance engineering learning ecologies, including: pedagogic strategies, supportive digital tools, embedded assessment tools, as well as relevant organizational knowledge. A community of course innovators has experienced building and using non-conventional approaches to learning that are aligned by design with visionary strategies to educate engineers for the twenty-first century and beyond (Crawley *et al.*, 2014).

Follow-up studies

The REDINGE2 pilot experience has not yet ended. During 2018-2, 8 of the 14 courses will be in their first-implementation phase, while the rest will undergo course calibration after formative evaluation. Each of these courses will be subject to effect and impact evaluation and, based on these results, it will be possible to establish the effects the intervention has had on student¨s soft skills and learning.

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