Lean-green manufacturing: collaborative content and language integrated learning in higher education and engineering courses

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Abstract

Lean and Green manufacturing processes aim at achieving lower material and labour costs, while reducing impacts on the environment, and promoting sustainability as a whole. This paper reports on a pilot experiment with higher education and engineering students, exploring the full potential of a collaborative approach on courses integrating the Portuguese Polytechnic of Castelo Branco engineering studies curricula, while simultaneously improving their proficiency in English. Content and Language Integrated Learning (CLIL) has become a key area of curricular innovation since it is known for improving both language and content teacher and student motivation. In this context, instructional design for CLIL entailed tandem work of content (engineering) and language (English) teacher to design learning sequences and strategies. This allowed students to improve not only their language skills in English but also their knowledge in the specific engineering domain content on green and lean manufacturing processes.

Key words: Industrial Engineering, Manufacturing Processes, Engineering Education, Collaborative Learning, CLIL

Introduction

Lean-Green Manufacturing derives from the Lean Manufacturing (or Lean Production) systematic method for the elimination of waste as it promotes both energy and material resources efficiency by reducing unnecessary consumption (Greinacher, Moser, Hermann, Lanza, 2015). Current companies that work on optimizing their social and environmental responsibilities can adopt and combine Lean and Green strategies to focus on waste reduction techniques (Fercoq, Lamouri, Carbone, 2016) in their manufacturing processes, or by implementing Lean-Thinking methodologies to manage their operations responsibly as regards to their environmental and societal impacts (Martínez, Javier, 2016). Nowadays, academia and industry have become increasingly interested in how to effectively employ environmental management (Fu, Guo, Zhanwen, 2017), as only such combined efforts may contribute to building green/sustainable competitive advantages. As such, the role of academia is related not only to the development of greener and leaner processes, but also to transmitting such knowledge to current and future graduates.

Engineering education plays a key role on the implementation of Lean-Green processes, as it requires from current and future engineers a commitment towards implementing effective operational and organisational changes. Crucial to teaching the next generation of experts is that they learn to think and act toward longer term change, as the future engineer will not only need to be successful in designing this process but also in its implementation (Mulder, 2016) one can discern two main intellectual cultures: an analytic one focusing on measuring problems and prioritizing measures, Life Cycle Analysis (LCA. As Lean thinking focuses on how companies may improve the organization of their staff's activities towards the elimination of waste where delivering more benefits to society and value to individuals, the same principles may be applied to those individuals in their personal life. This was the motivating principle of the current study, as a collaborative learning methodology was being implemented within combined groups of higher education and engineering students discussing the advantages and implications of integrating sustainability issues into engineering processes.

This study focuses on a collaborative pedagogical experiment carried-out in a Portuguese Engineering School during the spring semester of the 2016-2017 academic year, where a pilot exploratory experience was undertaken with the aim of assessing the potential of different approaches towards the instructional design of collaborative teaching and learning activities in higher education and engineering contexts.

Collaborative Learning and Collaborative Teaching Approaches

Collaborative learning can be defined as a learning situation during which students actively contribute to the attainment of a mutual learning goal and try to share the effort to reach this goal (Teasley, 1993). This type of group

learning methodology is considered a fundamental feature in higher educa-tion as it refers to activities during the learning process in which students collaborate to contribute to the attainment of mutual goals (de Hei, Strijbos, Sjoer, Admiraal, 2016; Janssen, Kirschner, Erkens, Kirschner, & Paas, 2010). In collaborative learning, students build knowledge by working on complex problems together, including solving the problem (individual contribution), contributing to debate of the individual contributions, and arriving at coop-erative solutions (Roschelle, 1992). Additionally, group learning activities in higher education can be considered a key ingredient of course designs (de Hei, et al., 2016) as they promote student engagement with others (peer dis-cussion or collaboration) and also with their own learning process (active learning) (Salaber, 2014).

Even though current efforts are put towards designing dynamic online learning environments to promote collaborative learning based on new digi-tal technologies (Duță, & Martínez-Rivera, 2015) or on social networks as collaborative learning tools (Agudo, Sánchez, Rico, Hernández-Linares, & Domínguez, 2013), such digital environments lack the face-to-face contexts that often enable teachers and peers to effectively contribute to each other's learning process and to assess the students' reactions as they work together. This allows not only understanding how the learning process is developing during the group activities, but also the role of social interactions during the knowledge sharing and acquisition processes. To this end, Jeremy Roschelle and Stephanie Teasley (1995) assert that in collaborative situations, learning occurs socially as a shared process of building knowledge.

Nowadays, higher education and engineering students must have a specific professional profile to meet current and future demands of the glo-balised and multicultural environments in which they have to «survive» not only professionally, but also at a personal level. Common situations like personal or professional meetings using Information and Communications Technologies (ICT) to communicate in non-native languages (e.g., English), geographical mobility, intercultural teams, amongst others suggest the need for learning English for Specific Purposes (Candel-Mora, 2015). Recently a new approach has been developed and tested that allows integrating a col-laborative approach towards content subjects and a foreign, non-native communication language in teaching-learning processes (Morgado, et al., 2014). According to David Marsh (2008), CLIL is a methodology in which non-language topics are taught through a foreign language. For Do Coyle, Bernardette Holmes and Lid King (2009), CLIL is a pedagogical methodol-ogy in which content and language are learnt collaboratively, at the same time, promoting the use of the foreign language as a tool to learn a specific topic rather than an end in itself. Learning from content and language inte-grated approaches allows collaborative activities that need to be planned, requiring implementing new approaches that may benefit the learning and teaching of a foreign language (Carrió-Pastor, & Skorczynska, 2015; Jacobs, & Dasilva Iddings, 2006) and, simultaneously subject specific content (termi-

nology, pragmatics). The same authors also state that when preparing activities based on collaborative learning, teachers must take into consideration that it is important to group students according to their language level, to give clear and simple instructions to the groups of students, to encourage interaction among students, to restrict the information to be given to learners and to encourage close cooperation. These approaches are seen as student-centred and focused on student learning.

An important collaborative language learning methodology is tandem learning, in which two native speakers - or two highly proficient speakers - interact and learn each other's native languages in reciprocal cooperation. This collaborative learning process can take place in face-to-face situations, or alternatively, at distance using regular or ICT communication tools. In face-to-face classroom contexts, this approach may be productively used for foreign language instruction in mixed language groups. Tandem learning is based on a social-interactional perspective on language learning, as language use can provide opportunities and context for language learning (Karjalainen, Pörn, Rusk, & Björkskog, 2013).

Collaborative work between teachers can take place in various situations, which may be globally classified as co-teaching. Co-teaching takes place when two teachers work together to plan, organize, instruct and make assessments on the same group of students, sharing the same classroom (Hartnett, et. al., 2013). There are myriad co-teaching structures that can be selected by cooperating teachers as a single method or as variations of existing co-teaching structures. Nonetheless, there are five basic co-teaching structures (Friend, 2011), namely the «one teach, one assist» model, (in which one teacher is assisting to the other that is effectively teaching); station teaching (when both divide instructional content and work in a classroom divided into various teaching centres and aiding any particular centre that may need help); parallel teaching (in which teachers plan jointly, but each one teaches the same content to different halves of the classroom at the same time); alternative teaching (where a given teacher manages most of the class, while the other teaches to a small group – inside or outside of the classroom – that may – or may not – be integrated with the main group's lesson) and, finally, team teaching (in which both teachers share the planning and the teaching to the students). In team teaching lessons are taught by the two lecturers, as they both actively engage into conversation to encourage discussion about the subject with the students. One particular type of team teaching is Tandem Teaching (TT), in which two teachers – usually with different strengths and abilities – work together in a classroom, turning an individual activity into a mutual experience. This type of collaborative teaching is particularly demanding, as it takes not only practice to be effectively carried-out, but needs the development of specific skills and dedicated tools. It also needs not only previous teaching experience by both lecturers, but also specific planning and preparation prior to every teaching session and some type of assessment at the end.

Mixed Combined Content and Language for Specific Purpose Classes

A pilot Tandem Teaching experiment was carried-out with higher education and engineering students, exploring the full potential of a collaborative approach on courses integrating the Portuguese Polytechnic of Castelo Branco engineering studies curricula, while simultaneously improving their proficiency in English as a foreign language. Such an exploratory educational experiment was based on a specific subject that has multiple approaches and interests for the typology of courses lectured at the local engineering School, namely Lean-Green Manufacturing. This course aimed at providing students with a comprehensive understanding of the key concepts associated with Lean manufacturing methodologies and sustainable production principles. Regardless of the manufacturing aspects of Lean Thinking and related Sustainable issues, they are transversal notions to all current and future graduates, as sustainability is a key concern for all companies and organizations that want to have a relevant role in today's markets and society in general.

As previously discussed, the current generation of higher education students need to be prepared to interact in a globalised world in which intercultural communication skills allow them to integrate and function in present and future multicultural environments. All students of the local Engineering School are offered a course of English for Specific Purposes (ESP) in their curricula. Nonetheless, the majority of students are not proficient in English. Most of them even consider their ESP course as not particularly motivating, as they are usually unable to show good progress in language skills through the widespread two-semester course in ESP when it solely focuses on language learning.

To promote a more effective attendance of the students to these mixed group classes, the time-schedule of the content and language classes of all students were superimposed, even though different classrooms were allocated for the course in Lean-Green Manufacturing and in English in the students' timetables. The local online learning environment (a Moodle platform) was also adapted to attain the envisaged collaborative goals, by allocating editing roles to both language and content teacher in both classes' digital webpages.

The current exploratory study aimed at implementing a collaborative approach on teaching and learning subject content and language. Mixed classes of higher education short cycle students combined with engineering students were selected to form a pilot group on collaborative learning. As an additional feature, both content and language teachers used a TT approach to teach in parallel to these groups of students both Lean-Green manufacturing topics and ESP. Bringing the groups of students together as a parallel course allowed them not only to share the work load between the teachers, but broadened the instructional design strategies to a wider set of aims and goals, alongside increasing the pedagogical challenges for the teachers to combine

methods and approaches attaining the goals envisaged for both content and language classes. This allowed them to turn their individual teaching activity into a mutual experience.

As asserted, TT is particularly demanding for the teachers, as it takes not only practice to be effectively carried-out, but needs the development of specific skills and dedicated tools. Therefore, a training of both content and language teachers in instructional design for CLIL took place beforehand. An analysis was made of the students' needs, linguistic skills and motivation to learn in English, as well as of the learning problems identified and discussed in the above section. Specific attention was also given at this analysis stage of the training needs of teachers to be involved in this collaborative experiment.

The pilot TT experiment was made to be intensively participated in by the students, requiring them to work to continuously interact with other students and/or with the teachers, working in groups, carrying out research tasks, presenting information to the class, amongst others, turning the class into a highly interactive and fast content and language learning environment. To this end, the planning and preparation stages of each session were particularly demanding for the TT content and language teachers, as they had to foresee in advance the main instructional strategies to attain specific goals and prepare tasks and methodologies to such an end. In preparing the sessions beforehand, the two teachers decided on who did what during the classes, aiming to share in equal amounts of time the class duration and supporting the other teacher during specific classroom activities. Such a parallel TT also allows both teachers the opportunity to observe and learn from each other, highlighting opportunities to improve when due and suggesting the use of different strategies for given tasks in specific situations. Even though there is no need for formal debriefing at the end of the classes, a small group meeting following the session allowed gathering of mutual comments on how the session had developed and how certain strategies had worked out and how other things needed to be improved in subsequent sessions. More detailed assessment took place in the subsequent meetings to prepare for sessions and after processing the students' feedback on overall impressions and/or related to specific tasks.

Teachers' and Students' Points of View

The collaborative learning groups gathered during these TT sessions on both content and language integrated teaching and learning sessions allowed not only students to take part in peer-to-peer knowledge creation situations, but also both the content and the language teachers to mutually contribute with their complementary fields of expertise to the group's knowledge building, group cognition and overall mutual growth. At the end, there was evidence that the dedicated instructional design strategies used in this TT approach had implemented active learning and student-centred methodologies that contrib-

uted positively to the students' learning processes. Overall, teachers found this was an enriching experience since they felt students were learning the content and the language at the same time and that their students were more motivated towards the learning experience.

The group learning sessions, which included classroom-based activities and e-activities, were globally structured and prepared previously to the pilot TT experience. Nonetheless, each session was designed in detail in each week of the experiment, following each group session and in the days that preceded the following class. The design of instructional activities allowed both content and language teachers to reflect and act on students' interaction, taking into account not only the course and session learning objectives and outcomes, but also detailed feedback of the students. In the preparation of the session's structure, as well as of the specific instructional tasks, feedback from previous sessions was always considered to improve the learning outcomes of the students, as teachers discussed the objectives, students' needs and learning strategies before and after the sessions.

At the end of the class each of the teachers wrote about their experience in a teaching log. The teaching logs collected the teachers' thoughts, feelings and experiences during and at the end of the class. They filled their teaching logs with their personal reflections and argued about their concerns, registering thoughts and observations in order to prepare the next class. Students' questionnaires were also analysed, as they regularly had to fill in questionnaires and answer short oral questions asked during the sessions in order to collect their opinions and observations.

Teachers' reflections and students' questionnaires and observations were considered every week to plan the following session, as new approaches and activities had to be created and developed to respond to students' needs and promote their increasing motivation. Online Moodle exercises were also used to adapt methods and to encourage technological experiences. As an example of the interactive input in the instructional design strategy planning, approximately one month after the beginning of this collaborative work, teachers were told by the students who were enrolled in the ESP class that they felt they had not learnt any specialized terminology. The teachers discussed with each other what they could do to help the students and increase their motivation. Due to that fact, methodology changed and several new activities and exercises were included in the classes. Students' responses to the questionnaires and their answers to short questions in class showed their motivation increased. Teachers' motivation towards this new methodology increased as well.

To implement such interdisciplinary collaborative approach between the content and language teachers – which was a new experience for both of them – some negotiation across their own cultures of/for learning and teaching had to take place not only during the class planning stages, but also in the classroom, as sessions were taking place. However, both teachers agree that it was a successful experience and that such «negotiations» contributed to the enrich-

ment of their own perspectives and skills as teachers, thus widening their personal and professional horizons.

This TT experiment allowed teachers to provide students with a comprehensive understanding of the key concepts associated with Lean manufacturing methodologies and sustainable production principles (from a content perspective), while also working on the fundamentals of Lean thinking in English (from the linguistic perspective), and allowing them to reflect on ways of eliminating waste in everyday situations while deriving more benefits for society and value for themselves. As this was the motivating principle of the current exploratory study, it proved the benefits of a collaborative teaching methodology in the process of integrating content knowledge with the development of communicative skills and terminology in specialised English for engineering.

The language course main objectives were to increase students' level of English and develop their communicative skills through group learning strategies. These communicative approaches aimed at enabling students to interact in different contexts and groups. Methodologies to expose students to a different context and content were created with the purpose of generating a learning environment where learners were invited to communicate in English.

At the end of the course a focus group interview was conducted by both the content and the language teachers. Students rated the experiment as an interesting approach. They also stated they felt more motivated towards the learning of the language, that the experience with two teachers in class, simultaneously and with different perspectives (language and content) was positive, and that they would like to repeat it. Students also mentioned they developed their communicative skills through the discussion exercises, the presentations and the writing activities they engaged in.

Future Developments

The experiment took place with groups of higher education and engineering students, as well as content subject and (foreign) language teachers to pilot collaborative approaches on teaching and learning engineering content while simultaneously improving their communicative proficiency in a foreign language, namely English for engineering.

Considering the exploratory nature of this pedagogical experiment, one can argue that the main goals of this collaborative experiment were globally attained. Nonetheless, different implications of Tandem Teaching in Higher Education can be further discussed. Aspects like the role of each of the (content and language) teachers in the students' learning process, their engagement to the experience, as well as the individual contribution of all actors in this collaborative teaching and learning approach should and can be further analysed.

Therefore, the implementation of further Tandem Teaching experiments are foreseen for the same local Engineering School, by broadening the students' engineering fields and topics in parallel learning, the use of online

learning environments in digital collaborative learning (such as online virtual exchanges or telecollaboration), and the further exploration of how content and language can be integrated to suit rich learning engineering environments for students where they are active co-constructors of their learning and can use English for communicating their research and collaborative practice.

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