Principles of Pedagogical Practice: CLIL and the PBL in Mechanical Engineering at LUT

Paula Haapanen[+], David Erent[+], Kimmo Kerkkänen[*], Harri Eskelinen[*]

[+] Language Centre, [*] LUT Mechanical Engineering, Lappeenranta University of Technology, Skinnarilankatu 34, 53850 Lappeenranta, Finland

Email: paula.haapanen@lut.fi, david.erent@lut.fi, harri.eskelinen@lut.fi

Abstract

In this paper, we describe how a material selection course was transformed into an interdisciplinary course involving mechanical engineering and foreign languages, and how the assessment changed from a traditional exam to a collaborative project-based evaluation. During the process, several challenges were encountered concerning timing, workload and pre-existing student expertise. However, the overall result was quite positive, as some students decided to continue learning French or German, and all students developed their metaskills in research and problem-solving.

Keywords: mechanical engineering; material selection; content and language integrated learning (CLIL); project-based learning (PBL).

1. Introduction

The Mechanical Engineering unit of Lappeenranta University of Technology (LUT) is committed to improving and adding value to the student learning experience. As such, it has been innovative in applying pedagogical methods that have not been traditionally used. For example, a project component called *LUT Sammio* (LUT Open Spaces) has been developed, which incorporates courses from business, mechanical design and electrical engineering (Kerkkänen & Eskelinen, 2013).

One of the newest pedagogical experiences concerns *Content and Language Integrated Learning* (CLIL) in subject courses. CLIL is novel at the tertiary level and even more so when it involves a 'languages other than English' (LOTE) approach and late introduction into the curriculum. Furthermore, it not only requires heavy initial human and time resources, but a change in perspective regarding how content is delivered and assessed.

In this paper, we describe how a material selection course was transformed into an interdisciplinary course involving mechanical engineering and foreign languages, and how the assessment changed from a traditional exam to a collaborative project-based evaluation. We will also elaborate on the challenges and successes faced during this experience and offer valuable insights to those who may be attempting similar endeavors, as well as suggestions for future areas of development. The paper is divided into six sections. In the first part, we will describe the motivation behind the changes to the course, including teacher motivation and cognitive development. In part two, we will briefly explain what CLIL and *project-based learning* (PBL) are, and elaborate on the changes made in order to integrate the language learning and the project-based approach. In section three, we will briefly compare and contrast the traditional delivery model with the new integrated model. Section four explains the project-based activity in more detail. In section five, we examine and discuss the challenges and successes of the piloting and finally we conclude with recommendations for future directions of development.

1.1 Motivation

The course BK20A2100 Structural Material has been offered at LUT in the Mechanical Engineering unit since 2006. Up until 2009, this course consisted of a traditional lecture and lab framework, where students would participate in two hours of lectures and two hours of lab work weekly over 14 weeks. Students were then required to present an individual research project, with an abstract in English, and to write a final exam.

However, in 2010, the engineering teacher felt that there might be more to gain by combining efforts with language teachers working within the Language Centre of the university.

There were many reasons for the integration and all of them reflect the idea of adding value to the learning experience. According to Jonassen (1995), students learn well if they experience their studies as meaningful and he outlines seven principles of meaningful learning:

- *Activity* - the idea that learning is based on the student's own actions, placing the responsibility of learning more on the student than on the teacher,
- *Intentionality* - related to awareness of the learning outcomes indicated for the course and ones they have indicated for themselves,
- *Constructivism* - the concept of building on prior learning and skills. Students can better learn new knowledge when it is connected with existing knowledge.
- *Collaboration and interaction* - learning is interactive, conversational and social. As a result, it creates a situation that facilitates all knowledge transfer but particularly tacit knowledge transfer.
- *Contextualism* – this requires that assignments are related to real life, either as simulated cases or based on authentic, existing problems.
- *Reflection* - students should be able to assess their own learning and reflect on their own conclusions, and
- *Transferability* – students can transfer what they have learned in one situation to another.

All of the things above contribute to increasing motivation, both of the students and of the teachers involved, and all of them are supported by both of the pedagogical principles used for the course: content and language integrated learning and project-based learning. These will now be explained in more detail in the following section.

2. Pedagogical Principles

In this section, we will consider the two main pedagogical principles being applied, which are CLIL and PBL, respectively. We have taken the liberty of presenting these principles in this order because in this situation they were applied in this order. First the foreign language component was considered and then because of the nature of the integration, project-based learning was adopted to better accommodate the assessment of collaborative work.

2.1 What is CLIL?

Content and language integrated learning is a "dual-focused approach in which various language-supportive methodologies are used which lead to a dual-focused form of instruction where attention is given both to the language and the content" (Coyle, Hood, & Marsh, 2010, p. 3) (see also the Eurydice report *Content and Language Integrated Learning (CLIL) at Schools in Europe,* (2006) (*Content and language integrated learning (CLIL) at schools in Europe,* 2006, p. 8)).

For the purposes of this application, the model being adopted is what Coyle *et al.* name the A2 model, which focuses on the development of key concepts and learner autonomy (Coyle et al., 2010). What is perhaps novel in this approach is that it is typically used with primary level education, whereas tertiary level education usually sees the adoption of more sophisticated models operating at a more advanced level of language proficiency in the vehicular language. However, tertiary level programs usually use English as the vehicular language as students have already attained a relatively high level in this academic lingua franca. The focus of the CLIL work being done with mechanical engineering here at LUT has a *Languages Other Than English* (LOTE) approach, meaning the introduction of other languages, in this case German and French, for socio-economic (i.e. the importance of local industries collaborating with German and French companies) and information access (i.e. accessing the newest research in specific areas directly connected to the selection of construction materials) reasons. Furthermore, the focus is on offering students an introduction to the language and not an attempt at attaining full proficiency. Therefore, the primary model seems appropriate. (Haapanen, Erent, Eskelinen, Wunderlich, & Varis, 2012)

As students discover the utility of the foreign language, they may be encouraged and more motivated to continue studying that language as well as the culture. This results in added value being injected into their learning experience and into their future marketability on the job market, particularly on the local or regional job market. As Coyle *et al*. (2010) state, they "...believe that CLIL as a promoter of LOTE has yet to reach its potential in the global arena...Pioneering work using a wide range of languages is gaining momentum and making a crucial contribution to developing CLIL pedagogies..." (Coyle et al., 2010, p. 9) We hope that our work will further contribute to this development. (Haapanen et al., 2012)

In many primary and secondary education contexts, the CLIL teacher is a content teacher who (most likely) is a non-native speaker of the language of instruction and who has (most likely) had little to no training in CLIL pedagogy (Llinares, Morton, & Whittaker, 2012). This description can be further generalised to CLIL in tertiary education as well,

particularly in light of the growing number of English language medium programs being offered in countries where English is not a national or administrative language. (Haapanen et al., 2012)

We are fortunate in that both language teachers involved in the project are native speakers of their respective languages. Therefore, they can offer invaluable support to both the students and the content teacher. This also speaks to a more team-teaching approach than a single-teacher approach as mentioned above. (Haapanen et al., 2012)

2.2 What is Project-Based Learning?

The term 'project' gives the immediate impression that someone is going to have to do something or determine something and report back on it. It is used at all levels of education with the goals of exploration, discovery and learning at its heart. It is one way to experience *learning by doing*.

As there are many ways to learn by doing, we need to better define what is meant by *project*-based learning (PBL). In their attempt to respond to the question above, Helle *et al.*'s (2006) review of project-based learning (PBL) leans on a definition by Adderley which states that:

1. *[projects] involve the solution of a problem; often, though not necessarily, set by the student himself [or herself];*
2. *they involve initiative by the student or group of students, and necessitate a variety of educational activities;*
3. *they commonly result in an end product (e.g., thesis, report, design plans, computer programme* [sic] *and model);*
4. *work often goes on for a considerable length of time;*
5. *teaching staff are involved in an advisory, rather than authoritarian, role at any or all of the stages – initiation, conduct an conclusion.* (Helle, Tynjälä, & Olkinuora, 2006, p. 288)

These authors claim that even after almost 40 years, this definition is still valid. In essence, there is a problem or an issue that the student(s) set out to solve or resolve. This process results in an end product, which, as Adderley stated could be, for example, a report, computer program or model that satisfies or responds to the question originally asked.

However, this definition of project-based learning could easily be confused with the concept of *problem*-based learning, also abbreviated as PBL; all parts of the above definition apply. Hmelo-Silver (2004) describes problem-based learning in her article as follows:

> *In PBL, students work in small collaborative groups and learn what they need to know in order to solve a problem. The teacher acts as a facilitator to guide the student learning through the learning cycle...students are presented with a problem scenario. They formulate and analyze the problem by identifying the relevant facts from the scenario...An important part of this cycle is identifying knowledge deficiencies relative to the problem. These knowledge deficiencies become what are known as the learning issues that students research during their self-directed learning* (Hmelo-Silver, 2004, p. 236)

One could agree that both definitions are very similar – both define and resolve problems, can involve collaboration but it is not absolutely necessary, have teachers acting as facilitators or advisors and involve initiative as well as a variety of educational activities. Therefore, we must ask ourselves what the distinguishing feature is between these two definitions.

In order to simplify the distinction, one could say that *problem*-based learning is more focused on gathering knowledge about the phenomenon or problem while *project*-based learning is more goal-oriented with the objective of applying knowledge to produce an 'end product' to satisfy the problem or issue. We acknowledge that this may be painting the above concepts with broad strokes; some may indeed argue that the aforementioned can be best represented by the old axiom *six of one, half-a-dozen of the other*, but for the needs of our particular situation, this distinction helps to clarify how we have applied the approach in our context.

In the material selection course, the project-based learning exercise was used as a *capstone* event, which means that it was "designed to integrate the subject material learnt during a specific course" (Helle, Tynjälä, & Olkinuora, 2006, p. 289) in contrast to the *project component* approach developed in LUT Mechanical Engineering by Kerkkänen and Eskelinen (2013), where they were synthesizing and applying knowledge from a number of coordinated courses in a broader fashion. In our case, the project was used to assess the knowledge gained and how well students were able to apply that knowledge to various scenarios of their own choosing within the confines of one course.

In conclusion to this section, we would like to emphasize that both of the pedagogical principles being applied in this case support the ideals of meaningful learning (see section 1.1 above). By employing both CLIL and PBL, students can engage in collaborative activity that builds on old, new and interdisciplinary knowledge. The topics are relevant and provide students with an opportunity to reflect on and transfer what they know to real life applications.

In the following section, we will briefly illustrate the differences between the original material selection course and the new integrated model. We will also explain the various tools and skills that have been incorporated into the new model.

3. Comparing the Models

The simplified comparison of the original arrangements of the course modules and the new set-up of the PBL-based and CLIL-supported model is presented in figure 1 and table 1. In the original model, all the course modules (i.e., foreign languages, project work and structural materials) were independent. In addition, language courses and project work were voluntary (indicated by a grey background). In the new model, the practical teaching of foreign languages and construction materials is integrated with the aims of simultaneously teaching project work skills.

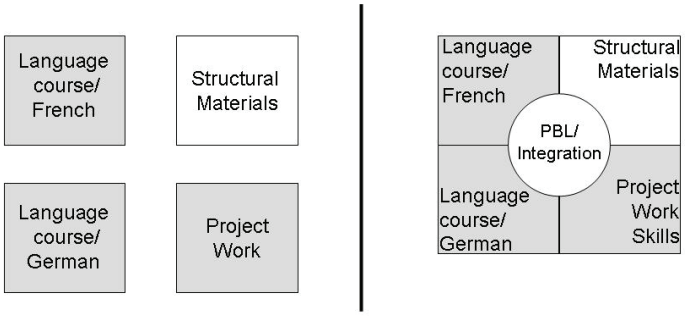

Figure 1: The simplified comparison of the original and the new teaching model

3.1 Support tools

3.1.1 Computer and online support

The work carried out in the new course was supported by a variety of computer-assisted environments. Students were free to select their means of communication and file synchronisation software (e.g. *Dropbox* or any other www-based application). The independent learning environments employed were LUT's own *Noppa*-portal (a light, custom-designed learning management system (LMS) used mainly for one-way communication from the teacher to the student) and *Moodle*. In addition, students had access to the university library's scientific databases in order to access and collect information. Students mainly used the *Scopus* database and members of the library staff provided support on how to make the most of said database's functionalities. During the course of the project, the language teachers gave instruction on how to use several web-based terminological databases and dictionaries, and the substance teacher introduced the students to some professional multi-language databases dedicated to materials. Our purpose was to provide the project teams with the kind of computer-based support that would allow them to carry out their project as freely as possible.

3.1.2 Language Learning

As stated above, in the new model, the focus *of* the language aspect is on offering students an introduction to a foreign language more than an attempt at attaining full proficiency. With that in mind, the communicative approach that has now become the norm in language teaching was abandoned in favour or a more straightforward and pragmatic one**,** where the target language is considered a means to an end, a key to access new, more cutting-edge information. The skills to be acquired had to match the students' needs in terms of project development. Therefore, the primary focus of the language courses was the acquisition of the necessary basic terminology (see table 2), as well as key words to facilitate research, and descriptive, practical instructions on how to build new complex terms out of smaller lexical units. In addition, students were encouraged to set up their own lexicon, based on their project's specific field. Before their final presentation, the students were asked to produce three abstracts: one in Finnish, one in English and one in the target foreign language. In order to achieve this last task, they had to fill a template with key

words that they had selected themselves and then adjust the template, with some guidance from the language teacher, to obtain a final, coherent text. This task is the only one for which the students had to operate in production mode rather than reception mode. The idea behind this was to show that the newly acquired skills are transposable. What was first used to access knowledge could now be used to achieve better visibility for the outcomes of the research.

3.1.3 Project Management

Students received a tentative timetable for their project work in the beginning of the integrated course. However, the timetable of the lectures (both in teaching foreign languages and structural materials) was fixed and the students were conscious of the coming seminar presentation and its deadline. The project work was carried out as teamwork. Students were free to select the members of their team and to designate their leader from among the team members. The leader's role was both to manage the team's work and to liaise with the teachers when the team had something to discuss concerning the progress of the project. The leader was also the person to contact any external industrial parties if that was relevant to execute the project work.

Table 1: Comparison between non-integrated and integrated materials selection course

	Non-integrated course	**Integrated course**
European Credit Transfer and Accumulation System (ECTS) credits	5	5 (material selection) plus 1 or 2 (German or French language) depending on the starting level
Lecture framework	14 weeks	14 weeks
Weekly lectures	2 hours, 28 hours total	2 to 3 hours, 35 hours total
Weekly lab (practical) exercises	2 hours, 28 hours total	3 hours, 42 hours total (these included German/French instruction)
Practical exercises	Individual practical work, including an abstract written in English	One to two German/French language exercises weekly, based on source materials given in lectures, weekly written exercises in German/French and an abstract in German/French for the seminar work group practical work, including an abstract written in English, German/French and key words in English and German/French
External guidance	no	Information retrieval skills taught by library information specialists
Separate language instruction	no	10 hours (advanced group in German)
Assessment	Exam	Final seminar project

4. Practical execution of the PBL exercise

Before the lectures began in earnest, students choose a seminar topic from a predetermined list of practical applications. The premise was that students would be given a free hand in deciding what aspect of those applications they would research and report back on, which would affect the material selection considerations they would have to make. Some examples of applications included on the list were marine radar technology, diamond mining and the recycling of construction materials. Each application had either German or French connected with it according to the reasons stated above in section 2.1.

The practical execution of the PBL activity is illustrated in figure 2. The stepwise progress of the project is presented in the large arrow in figure 3. Students' project work included six main stages, which they had to schedule within a 14-week period. The selection strategy of materials covered the industrial aspects, which we wanted to include in the project model. Students were asked to select their strategy based on the price-quality ratio; they could chose to maximize the lifetime of the product or minimize the cost. This required the team to consider a significant number of scenarios and to choose compromises based on their strategy.

The second stage of the project was to determine the requirements for the material selection process. We wanted to focus on the requirements set by "assumed" customers. The following two stages of the project were more or less data and information seeking from different sources. The goal was to introduce students to different methods of finding relevant information for solving a multidisciplinary engineering design task in a limited time period. Our

integrated project model also included the stages of manufacturability friendly material selection (Design for Manufacturing and Assembly = DFMA) and aspects of green and clean technology inside the project work.

To enable the students to solve the material selection task, we carefully considered what type of information and language skills they might need during their project work. These aspects are illustrated in figure 1 above and in figure 2 below, under the large arrow describing the stepwise project work. In addition to the basic lectures dealing with material properties of different material types and groups (such as metallic materials, polymers, ceramics, adaptive materials) we needed to find the right timing to teach the principles of systematic material selection, tools for collecting product's requirements, optimizing algorithms for material selection, manufacturability principles and principles of life cycle analysis (LCA) or life cycle cost (LCC) evaluation. The foreign languages were mostly used to support students' capabilities to find the most recent and relevant material data from scientific databases no matter what the original language of reference might be. In our case we had three foreign languages in use: English, German and French. Because we knew that the timeframe allocated to the project work was relatively tight, we had to find ways to introduce the right language skills at the right time and ensure that the information was limited to the most relevant part of those language skills. Therefore, as mentioned above, we decided to focus on important keywords and ways to find the key message from abstracts written in French and German. For the written report, we produced a template that was easy to complete with the relevant words describing the results of the project work.

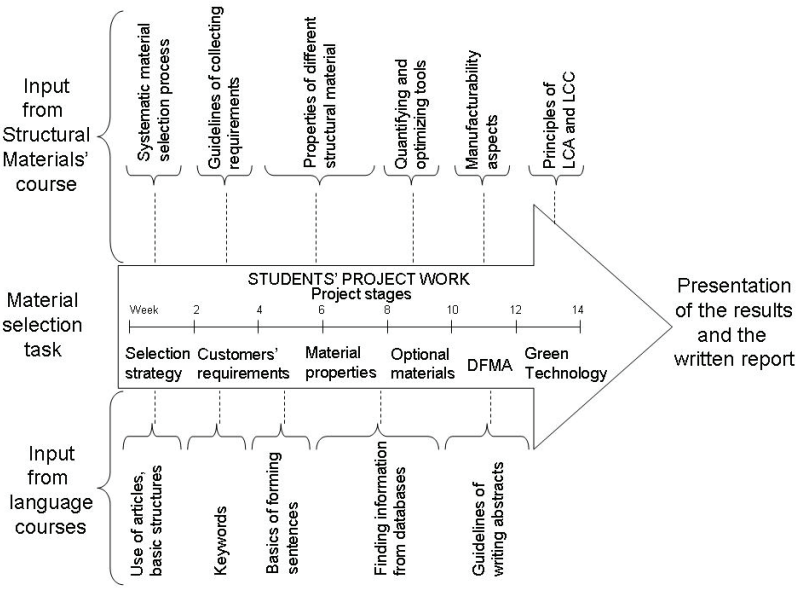

Figure 2: The practical execution of the PBL activity

Students were allowed to freely form their seminar groups. However, in order to be able to organize the language teaching and to ensure the reasonable industrial connection of the seminar topics, we composed the list of available topics beforehand and we connected these topics with the supporting foreign language (French or German). However, students could make suggestions to fine tune the given title and were free to choose the approach of their research. The topics were classified into three main groups to enable the different natures of possible projects (i.e., business-oriented, sustainability-oriented or product performance-oriented). Some examples of topics are presented in table 2 below.

Table 2: Seminar topics and project work nature

	Topic	**Supporting language**	**Project work nature**
1	Modern structural materials used in aviation industry	French	Performance-oriented
2	Structural materials in car industry to support safety aspects in case of traffic accidents.	German	Performance-oriented
3	Recycling of structural materials in car industry	French	Sustainability-oriented
4	German suppliers of ceramic materials	German	Business-oriented

The substance teacher in mechanical engineering provided information and examples regarding material selection in various contexts and applications during the lecture series. Students would then take that learning and apply it to the topic that they had chosen for their seminar work.

5. Challenges and successes

5.1 Timing

We found that there were challenges in implementing the 'just-in-time' idea with the language input for French. There were certain assumptions made during the planning stages about how the French language would be taught. These assumptions concerned which elements would be introduced at what stages and the amount of time needed to teach these elements. For example, instruction on the formation of compound words had to be extended from one week to two weeks in order to comprehensively explain the nature of how compound words are formed in French. This concept was essential to the success of the subsequent task of data acquisition using the French language medium. This required both the French teacher and the content teacher to readjust their content input schedules while keeping in mind that the course schedule was not renegotiable. These miscalculations may have been the result of the content teacher having a background in German but not one in French. Therefore the reference point used may have been more general, such as looking at how foreign languages are acquired in general as opposed to how specific languages are acquired (e.g., German vs. French).

5.2 Workload

Figure 3 illustrates the challenges we faced with the workload: the prerequisite knowledge that the students had was not adequate for this course. We assumed that students would have enough basic knowledge, skills and competences related to material selection concepts, such as the strength of materials, and manufacturing technology for example, as well as peripheral skills, such as project management and problem solving but their prerequisite substance knowledge was based on course books and lectures, and their skills in exploration and problem-solving were found to be somewhat lacking. As a result, more time had to be put into acquiring the content knowledge, and the language acquisition was sacrificed as a result. Therefore, in order to accommodate both substance and language learning, we feel that this type of project work-based model may better fit to the Master's level. The course will be moved to that level for the coming academic year.

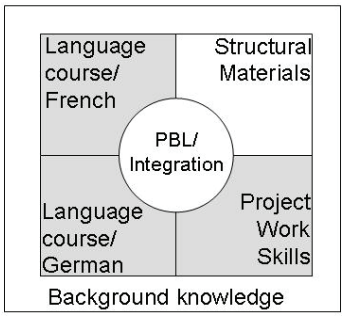

Figure 3: Student's adequate background information level is the necessary prerequisite for the successful execution of the project work model

The workload of the teachers should also be mentioned here. The total workload of teachers was about 380 hours of work for preparing the material and guiding the project work. While we did not perceive this as a problem per se, it is clear that this type of an endeavor is heavy in initial-time investment. However, certain types of work, such as task design, are reduced through the iterative process and leaning on previous experiences to make the work more efficient.

5.3 Level of expertise

In addition to a lack of substance knowledge, students were found to lack metaskills, such as exploiting academic sources and databases, and they were not familiar with the skills required for literature review in their own language. Therefore, using foreign key words for data searches was an added obstacle.

However, on a positive note, students did gain significantly in these skills during the course itself. This gain, combined with the collaborative nature of the final seminar work, enabled everyone to successfully complete the tasks and ultimately the course itself.

5.4 Language Learning

There were some students who continued their French and German studies after the project work during the semester following the pilot. This seems to indicate that there is some positive impact on the motivation to study foreign languages. In fact, a master's degree thesis was carried out during this CLIL experience to see whether the late introduction CLIL had any effect on the motivation to continue learning foreign languages, in this case French, in a traditional way. The study is ongoing and the results will be reported in future articles.

There were also some unanticipated and pleasant surprises that occurred. During the group work sessions, the French teacher, substance teacher and students were required to negotiate and renegotiate meaning not only in two languages (Finnish and French) but in a third language (English) as well, as the French teacher's Finnish technical vocabulary was not as strong as the students' and substance teacher's technical vocabulary in English. This put all the parties in a unique position to make meaning collaboratively. This is an example of Vygotsky's *Zone of Proximital Development,* where language and meaning are jointly constructed through collaborative activity between more knowledgeable and less knowledgeable peers (see Mitchell & Myles, 2004). Although this particular aspect has not been scientifically studied over the duration of this course, it is our strong impression that this negotiation of meaning in different languages has had a direct and positive effect on their perception of key concepts, in the sense that they have had to approach said concepts from a number of different perspectives in order to understand how the foreign language 'codes' describe them.

A final success resulting from the incorporation of languages is the value gained from the teacher's perspective. Not only did the exchange between the substance and language teachers promote the creation of new meaning as mentioned above, but it also resulted in a more practical advantage; the substance teacher was able to access new information that was immediately employed during lectures, which in turn added value to the students' learning experience.

5.5 Applications

The positive results of this PBL application were utilized to encourage and influence the *LUT Sammio* project component model at LUT, where the course modules were integrated between different faculties.

6. Conclusion

The Mechanical Engineering Department of Lappeenranta University of Technology has attempted different ways of applying project-based learning in various contexts; this paper describes one of them. PBL was employed as a way to evaluate how students applied both substance knowledge in the selection of construction materials and language knowledge to a particular task, in this case a final seminar work.

During the process, several challenges were encountered, such as accommodating the different natures of the foreign languages used leading to the renegotiation of the timetable within a fixed period. In addition, the students' prerequisite knowledge in basic mechanical engineering theories and metaskills (e.g. problem-solving and data search) was not as comprehensive as first thought, which lead students to prioritize the learning of substance knowledge over language knowledge.

However, the overall result was quite positive, as some students have decided to continue learning French or German, and the students did develop their metaskills in research and problem-solving. As a result of the added cognitive workload required for learning a new language, even at this minimal level, it was decided to move the integrated course to the master's level to allow time for students to gain the necessary substance knowledge and metaskills knowhow.

Future directions for development can include the investigation of whether an earlier and more simplified introduction of the foreign languages would have less of an impact on the cognitive workload of students. It will also be important to observe what happens when the course is moved to the Master's level of studies. Finally, it would be interesting to formally study what impacts the negotiation of meanings have in the integrated and collaborative project-based activities of LUT Mechanical Engineering.

References

Content and language integrated learning (CLIL) at schools in Europe. (2006). Brussels: Eurydice.

Coyle, D., Hood, P., & Marsh, D. (2010). CLIL: Content and language integrated learning. Cambridge: Cambridge University Press.

Haapanen, P., Erent, D., Eskelinen, H., Wunderlich, J., & Varis, J. (2012). Development and analysis of a professional-oriented CLIL model for university level mechanical engineering education. Proceedings of the 40th Annual SEFI Conference -2012, Engineering Education 2020: Meet the Future, Thessaloniki, Greece.

Helle, L., Tynjälä, P., & Olkinuora, E. (2006). Project-based learning in post-secondary education – theory, practice and rubber sling shots. Higher Education, 51(2), 287-314. doi:10.1007/s10734-004-6386-5

Hmelo-Silver, C. (2004). Problem-based learning: What and how do students learn? Educational Psychology Review, 16(3), 235-266.

Kerkkänen, K., & Eskelinen, H. (2013). Multidisciplinary learning model in product development for students of technology and business Project Approaches in Engineering Education 2013, Eindhoven, The Netherlands.

Llinares, A., Morton, T., & Whittaker, R. (2012). The roles of language in CLIL. Cambridge: Cambridge University Press.

Mitchell, R., & Myles, F. (2004). Second language learning theories (2nd ed.). London: Arnold.