THE ASSESSMENT OF STUDENT TEAMWORK TO PROMOTE CDIO LEARNING OBJECTIVES

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Abstract
École Polytechnique Montreal is currently completing its reform of the Mechanical Engineering curriculum according to the CDIO principles. In each year of this new undergraduate syllabus, students participate in a design project, which aims to gradually build the participants' practical experience in a collaborative product development context. In order to measure the academic and professional skills acquired during this project-based training process, a number of evaluation methods were customized in order to improve teamwork assessment. Besides the standard evaluation methods, the peer assessment system, the logbook assessment techniques, and the team mentoring approach are of particular interest. Peer assessment tools have been developed over the years to help students give feedback and qualify the contributions of other team members. The goal of these peer review evaluations is to build the ability of students to constructively comment on their performance. The introduction of student logbook evaluations further personalizes individual assessments in a project context. This initiative provides a unique insight on a student's progression, critical thinking capacities and his contribution to the project team effort. Finally, the team mentoring approach helps student teams to focus on the progress of the project and teachers to acquire a general view of the work achieved by the different teams. This paper will hence detail these progressive teamwork evaluation methods and then present elements of feedback from the various actors involved and also identify possible improvements to these new assessment methods.

Keywords: Project-based learning, Teamwork assessment, Peer review evaluation, Student logbook evaluation, Team mentoring.

Introduction

The reform of the Engineering curricula at École Polytechnique Montreal comprises a program specific first year (instead of a first year common to all departments), project based learning activities in each year, and more emphasis on "soft skills", e.g. communication and management skills. The objective is to include these new requirements within the various syllabuses while maintaining the strong scientific content which has been the hallmark of École Polytechnique since its foundation in 1873. For the Mechanical Engineering program, the CDIO initiative [1] was evaluated and was found to fulfill all the global requirements set out by the academic council and more. It offered the advantage of a clearly defined implementation process and a proven international benchmark to work with.

The fundamental values related to the reform were clustered in three areas of competence that need to be developed through the new Mechanical Engineering curriculum, namely *scientific and technical knowledge*, *professional skills*, and *personal skills*. The aim is to provide a cohesive learning strategy where students can gradually acquire a solid understanding of the environment in which complex products are developed. To achieve this goal, the revision committee focused on the development of project-based learning through Integrated *Learning Projects* (ILP).

In practice, this means that courses have been grouped to form cohesive chains of learning experiences within typical disciplines of the Mechanical Engineering domain. This approach fosters the development of a clear set of learning objectives and enables a high level of continuity between courses across the four-year program. The chains of learning experiences have been articulated around four design projects where students can apply their scientific and technical knowledge while progressively acquiring professional and personal skills. These ILPs offer a unique opportunity for the teaching staff to evaluate the students and to provide sustained teaching support on more practical aspects of the engineering profession. Table 1 presents the core objectives of the four ILPs developed at École Polytechnique Montreal.

Table 1. The four Integrated Learning Projects at École Polytechnique Montreal

	Integrated Learning Project (ILP) Description
Year 1 ILP	• 1 term cornerstone project: 3 case studies and design exercises • Teams of 4 to 6 mechanical engineering students • Work focussed on communication skills, teambuilding experience, project management tools and practices • Set in a controlled design solution space in both time and scope
Year 2 ILP	• 1 term cornerstone project, presented in the form of a design contest • Teams of 5 mechanical engineering students • Work focussed on conceptual design and prototype building/testing • Set in a closed-ended, rule-based design solution space
Year 3 ILP	• 1 term cornerstone project • Individual assignment submitted by local companies or research laboratories • The students answer a design specification document, manage budgets and project timelines
Year 4 ILP	• Capstone project covering 2 terms with industrial partners • Teams of 20 students from École Polytechnique, the School of Industrial Design, and the School of Business and Management. • Open-ended product design where the solution must be achieved by using virtual prototyping systems and advanced collaborative tools. • Work focuses on Integrated Product Team management, product information management, and professional communication skills.

The evaluation tools to support the new assessments methods associated to the aforementioned project-based learning initiatives are being developed with the help of the MATI Montreal research centre (La Maison des technologies Roland Giguère). Indeed, this inter-faculty research centre (École Polytechnique Montreal, University of Montreal, and HEC Montreal) is dedicated to the development of knowledge, methods and tools for the efficient integration of information and communication technologies in sciences, mathematics, engineering, and management educational programs. This paper first presents the overall learning assessment process and associated methods prescribed by the CDIO approach, before detailing three assessment methods specifically designed for the project-based learning activities implemented in the Mechanical

Engineering department at École Polytechnique Montreal, namely *peer assessment*, *logbook assessment* and *team mentoring*.

The overall learning assessment process and associated methods prescribed by the CDIO approach

"*Student learning assessment measures the extent to which each student achieves specific learning outcomes*" [1]. The CDIO syllabus has therefore established a formal learning-centered assessment process [2] to monitor the achievement of the students and also to improve teaching. This process can be decomposed in four phases, namely the specification of learning outcomes, the alignment of assessment methods with learning outcomes and teaching outcomes, the use of a variety of assessment methods to gather evidence of student learning, and the use of assessment results to improve teaching and learning [1]. This paper focuses on assessment methods customized at École Polytechnique Montreal for project-based learning activities. Table 2 therefore illustrates the first phase of the CDIO learning assessment process – the specification of learning outcomes – by providing the reader with the details for each one of the four ILPs included in the new curriculum.

Table 2. Learning outcomes for each Integrated Learning Project (ILP) at École Polytechnique Montreal

	Overarching Learning Outcomes		
	Personal and Interpersonal Skills	**Product, Process, & System Building Skills**	**Disciplinary Knowledge**
Year 1 ILP	• Identification of personal strengths and weaknesses • Oral presentation skills • Experience different team roles: meeting chair, secretary, participant • Written communication for the workplace (logbooks, summaries, technical reports) • Communication in English	• Definition of product requirements based on a functional approach • Conceptual design of a simple product using CAD tools. • Detailed design and analysis of a complete solution.	• Statics • CAD modeling • Solid mechanics
Year 2 ILP	• Use of a logbook (2nd experience) • Management of a project portfolio • New team role: project manager • Time and resource management • Technical reports	• Conceive, Design & Build experience through a design competition • Testing for gathering design data	• Dynamics • Tolerancing • CAD modelling • Manufacturing
Year 3 ILP	• Use of a logbook • Time management • Oral presentation • Technical report	• Relative to the project	• Relative to the project
Year 4 ILP	• Teambuilding experience • Project management • Multidisciplinary team experience • Executive report and presentation	• Complete CDIO cycle • Certification issues	• Vibration • Fatigue • FEA • Optimization, etc.

Once the learning outcomes have been established it is crucial to define appropriate assessment methods. The CDIO approach [1] divides these methods into 5 categories, each with specific assessment objectives:

- *Written and oral questions:* essentially for the assessment of students' conceptual understanding. Written examinations enable to evaluate a large number of students, while oral questions help to uncover students' misconceptions.
- *Performance ratings:* the assessment of student know-how is usually achieved by the observation of the students performing specific tasks. Predefined observation criteria are necessary to evaluate the quality of the performance with rating scales that reflect degrees of quality.
- *Product reviews:* design reviews, widely implemented in industry in a stage-gate approach [3] to product development, are key milestones which are used to control progress and verify the quality of the work achieved [4]. This process is often adapted in academia and the design review becomes an ideal opportunity for the teaching or supervising staff to assess the demonstration made by the students and review the physical product under development [1].
- *Journals and portfolios:* journals, also known as *logbooks*, and portfolios are again engineering tools widely used in industry [5]. An engineer's logbook is a key document where individual contributions to a project and design rationale are made explicit. They are therefore an ideal source for assessing a student's achievement within the context of a project-based learning activity such as ILPs.
- *Other self-report measures:* students can be asked to reflect on their learning experiences through inventories and questionnaires as a means to measure individual achievement and to evaluate the overall educational program in place [1].

Table 3 illustrates this categorization by classifying the various assessment items found in the new Mechanical Engineering curricula at École Polytechnique Montreal according to the 5 aforementioned types of assessment methods.

Table 3. Assessment items for each Integrated Learning Project (ILP) at École Polytechnique Montreal

	Written & Oral Questions	**Performance Ratings**	**Product Reviews**	**Journals & Portfolios**	**Other Self-Report Measures**
Year 1 ILP	• Mechanical dissection exercise • Oral questions during presentations	• Peer evaluation grid • Peer evaluation of oral presentations	• Technical report and oral presentation	• Logbook	• Competence and Preference Sheet [6] (CPS)
Year 2 ILP	• Oral questions during final presentation • Team mentoring	• Peer evaluation grid	• Technical report and oral presentation	• Logbook • Portfolio	
Year 3 ILP	• Oral questions during final presentation	• Peer evaluation of final presentation	• Technical report and oral presentation	• Logbook	
Year 4 ILP		• Peer assessment	• Industrial design review	• Logbook • Portfolio	• Myers-Briggs test, CPS

The assessment process and methods presented in this section cover an entire evaluation spectrum, nevertheless this paper will focus more particularly on a number of specific assessment methods developed at École Polytechnique Montreal. Based on past experiences, the authors believe that peer review evaluation, logbook assessment, and team mentoring are three methods that warrant a more detailed description and analysis for the benefit of a rich CDIO approach to project-based learning. These are presented in the next section.

New assessment methods and tools to support project-based learning within a CDIO framework

When starting the new Mechanical Engineering syllabus, all 1st year students are enrolled in the "Teamwork and Leadership" course where key theoretical aspects of interpersonal communication, team dynamics and organization are covered. This course has established itself as a prerequisite to all ILP offered by the department. The activities proposed help the students understand the possible barriers to efficient teamwork organization and offer strategies to overcome them. Closer to the topic of this paper, the experience and knowledge gained once the students complete the course has been found crucial to effectively implement a number of new team assessment methods. Indeed, topics such as "social relationships in the workplace", "active listening and constructive feedback", "team dynamics, roles and leadership", "effective decision making in teams", "collaboration and division of tasks", all contribute greatly to the students' understanding of the three assessment methods and related project-based tools presented in the following sections. The authors and their colleagues have all noticed an enhanced receptiveness and enthusiasm from the students since the "Teamwork and Leadership" course has been introduced in its current format. The three customized assessment methods, namely *peer assessment*, *logbook assessment*, and *team mentoring* were chosen not just for their novel approach to teamwork evaluation but also because they double up as useful teamwork management tools, which will undoubtedly help the students in their future careers as engineers.

Peer assessment

<u>Objectives</u>. For the CDIO initiative, *peer review evaluation* or *peer assessment* is one of the tools mentioned in the "product review assessment" method. Nevertheless, the authors consider the tool to be also a very efficient way to measure individual performance in a team environment. In practice, the peer assessment is in itself an experience which helps the students to develop specific personal skills, such as communicating constructive feedback to peers (critical or positive) and managing conflicts in team situations.

<u>Context.</u> Two main approaches to peer assessment can be outlined from the various techniques developed across the ILPs at École Polytechnique Montreal, namely an *individual peer assessment* and a *team peer assessment*.

In the *individual peer assessment* method, a student's work is evaluated by his teammates according to a number of predefined criteria. The results of this type of evaluation need to be kept confidential to avoid further conflicts between members of the project team. In this case the results aim to reveal any possible tensions within the team and also to detect organizational problems in a team's approach to project management.

The *team peer assessment* method can be compared to a critique, where a team will analyse, criticize and evaluate another team's work. In this case, the results are usually communicated directly between the students, verbally or in writing. Indeed, in this type of assessment process, the students have been found to be far less sensitive to critics as they are directed to the group rather than to the individual. Also the discussions generated by this approach often provide constructive feedback for both the team of reviewers and the team presenting the work. It is important to note that the teaching staff must help constructive feedback between teams by providing them with assessment criteria and making them aware of communicating their comments in a positive approach to avoid conflict.

The authors have chosen to describe in detail the *individual peer assessment* process as this type of evaluation meets far more resistance from the students *than its team peer assessment* counterpart. Because of this observation, the teaching staff has dedicated a sustained effort over the years to optimize the process and tools related to this approach. In order to provide the reader with a pragmatic view of the work achieved, the 1st year ILP peer assessment process and tools have been chosen as an illustrative example. As summarized previously in table 1, the 1st year ILP teams up 4 to 6 students to work on three different case studies over a term. The teams are formed by the teaching staff based on a preliminary questionnaire, the Competence and Preference Sheet (CPS) [6], which seeks to highlight each student's preferences and personality in a working environment. The objective is to bring different types of students to work together in a team, effectively forcing them to experience conflicts and to subsequently overcome team barriers related to a heterogeneous team composition.

Process. At the end of each case study, the students are asked to individually complete a *peer evaluation grid* similar to the one presented in figure 1.

EVALUATOR	NAME		SURNAME		STUDENT ID	
TEAM #						
CASE STUDY #						
ROLE						

NOTE: Comments are personal, rated according to the following scale and they are to be returned CONFIDENTIALLY to the teacher

SCALE: 5 - Excellent, 4 - Superior to team average, 3 - Team average, 2 - Below team average, 1 - Unsatisfactory
* Compulsory when rating is different than 3

TEAM MEMBERS	Interest and motivation at work	Comments*	Contribution during meetings	Comments*	Completion of assigned tasks	Comments*	Contribution for the reports and oral presentations	Comments*	Total	Deviation
	3		3		3		3		12	0
	3		3		3		3		12	0
	3		3		3		3		12	0
	3		3		3		3		12	0
	3		3		3		3		12	0
								AVERAGE	12	0

Figure 1: The peer evaluation grid used in the 1st Year Integrated Learning Project

The grid depicted in figure 1 is effectively an Excel spreadsheet where the cells highlighted in grey are generated automatically and therefore not modifiable by the user. A macro has been developed to facilitate both the generation and the compilation of these peer evaluation grids. The distribution and collection of the individual sheets is done entirely through the ILP course website which is configured so that the transfer of data remains confidential.

To complete the Excel spreadsheet, the students are given the following instructions:

- The ratings are set by default to 3 for each evaluation criteria
- A comment must be inserted with any rating different to 3
- The comments made must reveal a descriptive or experiential type of feedback [7]. This means that the students must make comments based on facts rather than impressions, or they can also explicit a feeling or emotion related to an interpersonal experience.
- The final rating for each team member is a measure of the standard deviation to the team average. The deviation is then added to the grade given by the teacher to the team report for each case study.

The peer assessment in the 1st Year ILP has two major outcomes that will be further detailed in the next paragraph, namely to provide a measure of individual contributions to a team effort (ratings) and to highlight any conflicts or organizational issues between team members.

Finally, the overall peer assessment process has been summarized in figure 2 from both the student's point of view and the teacher's perspective.

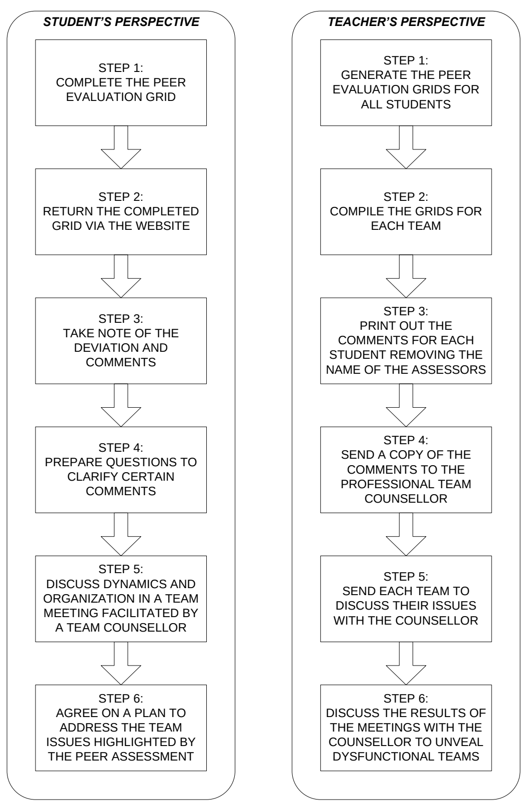


Figure 2: The overall peer assessment process from both the student's and the teacher's perspective

<u>Outcomes</u>. As mentioned previously, the peer assessment process for the 1st year ILP generates a measure of individual contributions to a team effort. The ratings proposed in the peer evaluation grid (figure 1) aim to measure the involvement and contribution of the rater's teammates according to 4 criteria:

- *Interest and motivation at work:* this criterion measures the involvement and motivation of team members during each case study. Punctuality, generation of new ideas, inquisitiveness and eagerness are some of the cues that the rater will look for to grade his colleagues.
- *Contribution during meetings:* in the 1st year ILP, a strong emphasis is made on the organization and management of regular team meetings. The students are shown how to efficiently manage the contents of the meetings using agendas and meeting minutes.
- *Completion of assigned tasks:* project scheduling and division of tasks is another team practice of importance which is introduced in the 1st year ILP. At the start of each project, the teams are asked to evaluate the overall necessary tasks required to complete the assignment and to use schedules to follow up on the progress of the project.
- *Contribution for the reports and oral presentations:* for each case study, the teams hand in a final report and two to three teams are asked to present their work in an oral presentation. During the term they are also asked to make oral presentations on general engineering topics in front of the class.

For each criterion, the rater must assess if the contribution of the ratee is in line with the rest of the team, below average, or above it using a scale from 1 to 5 as shown previously in figure 1. In order to provide an objective grading system, it is the standard deviation to the team average that is taken into account. The resulting deviation is then added to the grade given by the teacher for the final report, resulting in an individualization of the final report grade. The following mathematical approach shows how this weighting of the final report is achieved:

- With the use of the peer assessment grid, the rater (i) evaluates his teammate (j) with a grade N_i^j $\left(4 \leq N_i^j \leq 20\right)$ based on the rating system presented in figure 1
- The average (A_i) of the grades given by the rater (i) is $A_i = \frac{\sum_{i \neq j} N_i^j}{n-1}$ with (n) the number of participants in the team
- The deviation (D_i^j) of member (j) with the average (A_i) is $D_i^j = N_i^j - A_i$
- The cumulative deviation average (DC^j) for member (j) is therefore $DC^j = \frac{\sum_i D_i^j}{n-1}$
- The final individual grade (R^j) for member (j), based on the overall grade (R) given by the teacher for the final team report, is $R^j = R + DC^j$

The individual peer assessment method presented in this paper is also used as a tool to highlight positive attitudes, conflicts, or organizational issues within the team. Communicating issues between team members is not an easy task, even for experienced professionals and a complete team counselling process has therefore been optimized over the years.

Once the results of the peer evaluation grid are compiled, the teaching staff can then generate a summary of the comments made to each student. The comments, of course, are kept anonymous and are handed back to the student along with the cumulative deviation average (DC^j). A copy of the comments is also passed on to a professional team counsellor impersonated by one of the members of staff teaching the "Teamwork and Leadership" course. The 1st year student teams are then invited to discuss the results of the peer assessment and the underlying team issues uncovered by the various comments. The meeting is chaired by the team counselor, who follows a precise team regulation process. The aim of the meeting, which can last up to 45 minutes, is to stimulate the students to:

- Identification, development or adjustment of a team code of conduct (for both work organization and team atmosphere)
- Discuss or clarify the issues which have emerged from the peer assessment
- Propose strategies to improve both the team's organization and interpersonal dynamics
- Agree upon a common vision of the team's interpersonal dynamics

To achieve these goals, the counsellor promotes the communication of both positive and critical feedback. In this context, interpersonal feedback is communicating information on the way a person's words and actions affect the rest of the team. As the comments must relate to experiential or descriptive feedback, the counsellor facilitates the meeting by avoiding systematic and destructive accusations between team members. For more details on the team counselling strategies employed, the authors invite the reader to study [6]. Table 4 illustrates the type of positive or critical feedback expected in the peer evaluation grid and during the team counselling meeting.

Table 4. Examples of positive and critical feedback according to the peer evaluation criteria

Peer evaluation criteria	Examples of positive or critical feedback
Interest and motivation at work	CRITICAL. "During the last two team meetings, I noticed that you were checking your emails while we were planning out the tasks for the week to come. As a consequence the meeting lasted far longer than expected ..."
Contribution during meetings	POSITIVE. "Since you suggested we should hold a review of actions and tasks at the end of each team meeting, I noticed that our teammates were paying more attention to one another and that the tasks were better understood in general"
Completion of assigned tasks	CRITICAL. "As you didn't hand in your work to me before the agreed deadline, I had to reschedule all my activities that day to be able to correct your document!"
Contribution for the reports and oral presentations	POSITIVE. "I very much appreciated the effort you put into the correction of our final report, it had a positive impact on our final grade and on my personal motivation within our team ..."

Finally, in order to generate new team strategies to overcome specific organisational or interpersonal dysfunctions, the counsellor asks the team to list their strengths, the aspects that need to be improved and the subsequent actions that need to be taken. During the next team counselling meeting (each case study ends by one of these meetings), the counsellor verifies if these decisions have been followed up and implemented within the team.

Logbook assessment

Objectives. It is common and sometimes legal practice for engineers and designers to keep logbooks and they represent one of the most important sources of design information and knowledge for a company or an individual [5]. In an academic context, the use of a journal helps to reveal students' critical thinking and provide evidence of their individual contributions in situations where there may be no final tangible product [1]. Guiding students towards a structured and systematic approach to maintaining a logbook is the main objective behind the logbook assessment method described in the following paragraphs.

<u>Context.</u> Much of what is known about engineers and inventors of the past has been extracted from their historic working papers and notes. Perhaps the most famous example of this is Leonardo da Vinci's (1452-1519) notebooks. From these notes, it has been possible to understand some of his designs and even reproduce them, demonstrating the amount and potential value of the information contained within these personal notes [5]. In a similar way, student logbooks or journals offer an ideal opportunity for the teaching staff to measure reasoning skills and distinguish individual contributions in a project-based learning context [1].

In general, logbooks take the form of a hardback book held by either an individual or project team. These logbooks are used to record information which describes the results of activities and tasks, for example:

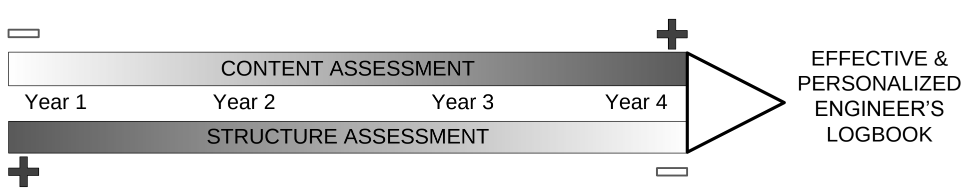
- fundamental design knowledge
- design information and rationale that supports decision making
- the results of analysis and modelling, including failures as well as successes
- informal information regarding suppliers and customers
- the outcome of discussions or meetings with experts and colleagues

In certain industrial domains, such as aerospace or civil engineering, logbooks are part of engineering practice with a legally binding status. Indeed, the information contained in these journals can be used for design audit purposes, as a legal record for accountability, or for Intellectual Property issues.

The development of ILP across the new Mechanical Engineering curriculum is therefore an ideal opportunity to familiarize engineering students with the practice of maintaining an individual or project logbook. The process detailed in the following paragraphs covers the evolution of the logbook assessment from year 1 to year 4, to demonstrate how a key industrial practice can be fostered through project-based learning activities.

<u>Process.</u> The assessment process aims to support the development of an effective and personalized practice for maintaining a logbook. As shown in figure 3, this involves the evaluation of student journals according to both their content and their structure. Nevertheless, the focus of the assessment method gradually shifts between content and structure evaluation as depicted in figure 3.

Figure 3: Focus of the logbook assessment across the 4 year program at École Polytechnique Montreal



While in the 1st year ILP the teaching staff places a strong emphasis on the information elements that must be present in the student's logbook, in the 4th year ILP the assessment is solely directed towards the contents of the journal. It is therefore expected that senior students have understood the necessity to use a number of structural informational elements and that they have enough experience to adapt them to their personal needs.

During the course of the 1st year ILP, logbooks are assessed regularly (at least 3 times for each student during the term) in order to provide a continuous feedback to the students. Here, the teachers focus more on the information entry types and the overall structure of the journal rather than the quality of its contents. The students are therefore given the following guidelines in order to structure their logbooks:

- Identification of the logbook (name, project, term/year) on the front cover or the first page.
- Names and details of team members on the last page or back cover.
- Each team must agree on a code of conduct and make a note of it in their individual logbooks.
- The first 2 pages are left blank for the table of contents; this enables an indexing of the logbook towards the end of the project. Page numbers must also appear to facilitate searches.
- For each new entry in the logbook, the date (and time) must appear before the text, calculations, sketches or graphs.
- If the student works on another medium then a reference to this must be made in the logbook (e.g. a filename or website address).
- A summary of the completed tasks and the time necessary to achieve them must be noted at the end of each course.
- Notes relating to any activity (during or after classes) in the context of the ILP must be visible in the logbook.

In order to assess the logbooks, evaluation grids are used by the teachers. These tables list the information entries that are expected to be found according to the structure guidelines mentioned above and the contents of the 1st year ILP activities. An example is shown in table 5.

Table 5. Excerpt of a logbook evaluation grid for the 1st year ILP

Evaluation items	Y/N	Comments
Structure		
identification		
team members		
page numbers		
table of contents		
dates		
timing		
Contents		
Entry on student presentation		
Entry on meeting #		

The grid is then used to rate the performance of each student using a standard scale from A to D. Each time logbooks are evaluated, the rated student is asked to show his logbook to his other teammates so that they can discuss its structure and contents between them. This technique fosters the share of best practices between students, and at the end of the term the grades are usually high.

Outcomes. With the regular assessment of logbooks for all ILP implemented in the new Mechanical Engineering curriculum at École Polytechnique Montreal, the students are gradually accustomed to the use and effective management of a logbook. The structure imposed in the 1st year ILP is a necessary formative step for the students, who are initially reluctant to the use of this engineering tool.

It is noticeable that this negative attitude quickly evolves as the scope of the projects and case studies expand. Even at the end of the 1st year ILP, a significant number of students are concerned about being able to retrieve their logbooks after the final assessment. The assessment of individual logbooks in the 4th year ILP is also met by the students with reluctance, but for positive reasons: they consider it as their main source of information to carry out their project tasks and therefore see the assessment as a possible delay for the progress of their work. The evolution of the aforementioned students' attitudes towards the logbook is an encouraging sign for the teaching staff that this valuable engineering practice is now well implemented in the curriculum.

Finally, it is important to note that from the 2nd year ILP onwards, project logbooks or project portfolios are introduced. These tools are also common practice in industry and from a pragmatic educational standpoint they enable the teachers to make a regular check on a team's progress without having to confiscate a student's personal logbook for a penalizing amount of time. Individual student logbooks are therefore evaluated only once or twice during the duration of the 2nd, 3rd, or 4th year ILP, but because the assessment is mainly focused on the contents, the correction process is far more demanding for the teacher than for the 1st year ILP.

Team mentoring

Objectives. The peer assessment presented earlier in this section focuses on team dynamics and team organization. A mentoring or coaching approach has also been implemented in order to address project management and engineering design issues. The approach gradually evolves towards a professional consultancy exercise for the 4th year ILP. These assessment activities are not sanctioned by a grade and they primarily retain a guidance, awareness and verification objective, although the consultancy time provided by industrial partners involved in the 4th year ILP are usually billed in the project's "virtual budget".

Context. Team mentoring is initiated in the 2nd year ILP. It is the first project-based course where the students are involved in a complete and competitive design project. For this reason, a number of project management tools introduced in the 1st year ILP become of indispensable use if the team wants to succeed. It is also important to mention that there are resource and organizational issues related to the introduction of the team mentoring activity in the 2nd year ILP rather than in the 1st year ILP. Indeed, in the 2nd year ILP there are fewer teams involved and they are supervised by two teachers; this facilitates a weekly team mentoring effort.

Process. For the 2nd year ILP, the teacher holds a weekly mentoring meeting with each team during 15 to 20 minutes. Because of the competitive nature of the project, and the infinite number of possible solutions available, the teacher prepares a general grid, as shown in figure 6, in order to provide impartial guidance to all teams. Here the focus is more on project management than technical/scientific issues.

Table 6. Excerpts from 2nd year ILP team mentoring assessment sheets

Week 10 – Detailed design phase		
Meeting agendas and minutes?		
Use of analytical software?		
Meetings during the week?		
Have your detailed drawings progressed?		
Week 11- Prototype		
Standard parts?	Number?	Purchased?
Manufacturing drawings?		
Week 12- Prototype		
Parts to manufacture?	Number?	Finished?
Has testing started?		
Organization for the competition day?		

For the 4th year ILP, the context is different; the teams are not competing and the design requirements are far more complex. The teaching staff and the industrial partners (clients) involved are therefore supporting the team in a role closer to the one a consultant would take in industry. They act on specific engineering or project management issues with no guarantee of actually providing a definite solution to the problem. To avoid overwhelming the industrial experts involved in the projects with difficult questions, the student team must send their information requests via email. This enables the supporting staff to monitor the requests and provide a consultancy bill at the end of the project, which is deducted from the team's budget.

Outcomes. The team mentoring exercise help the students measure their progress in the overall scope of the project. For the teachers, it is also an ideal opportunity to assess the progress of the entire group of student teams.

Discussion and future developments

This paper has described and illustrated in detail 3 key assessment methods that have been developed to support project-based learning activities. Moreover, these methods were chosen because they offer an efficient framework to foster specific collaborative skills that past engineering curricula have struggled to achieve, namely:

- Interpersonal relationships in the workplace (peer assessment)
- Team management and leadership (peer assessment)
- Engineering design information and knowledge management (logbook assessment)
- Project management (team mentoring)

Although these assessment methods and tools provide satisfactory results, they are the fruit of a continuous effort from the teaching staff and can still be improved. In order to pursue this quest for excellence, the teaching staff involved in the various ILPs holds weekly team meetings to discuss activities, contents, and assessment methods in order to make necessary adjustments during the term. At the end of each term, similar meetings are held between coordinators of each ILP in order to promote best practices across project-based activities implemented in the Mechanical Engineering department at École Polytechnique Montreal.

For the assessment methods presented in this paper, the following future developments are under consideration for short term to medium term implementation:

- The MATI will help to develop a web version of the peer evaluation grid in order to alleviate the distribution and collection process overhead.
- In the 2nd year ILP, the role of *project manager* will have a weight of 2 in the peer assessment process to account for the extra responsibilities involved with this role.
- Once the new Integrated Teaching Laboratory [8] will be finished, a study to implement Tablet PC in each team cubicle will carried out. These would replace team portfolios.
- Team mentoring must be adapted for the 1st year ILP, as the first experience held this year was very promising.

Conclusion

The assessment methods discussed in the paper and highlighted in figure 4 have proven to be very effective for the measurement of individual achievement within a team-based learning experience. Figure 4 illustrates the overall framework in which the various actors, assessment processes and key deliverables interact in order to foster this unique project-based learning experience.

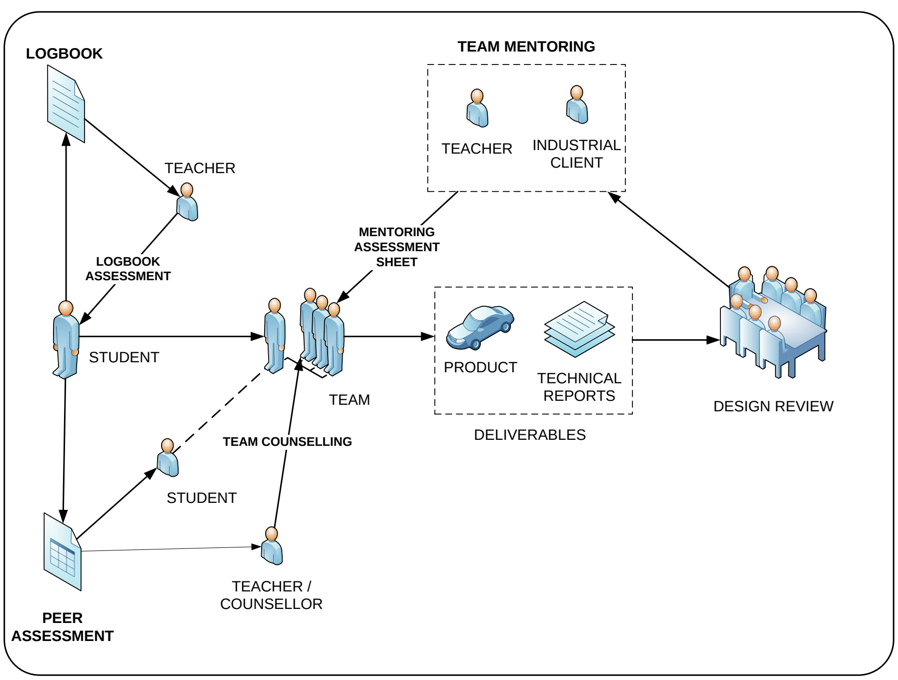


Figure 4: The framework to support Integrated Learning Projects at École Polytechnique Montreal

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Biographical Information

Greg Huet is Research Associate at École Polytechnique de Montréal (Canada). He completed his PhD thesis in 2006 in the field of "design information and knowledge management". Greg is currently working on a number of research projects involving the use of new PLM tools to support collaborative engineering design activities. He is also one of the teachers/supervisors for the first year design project.

Bernard Sanschagrin is Professor at École Polytechnique de Montréal (Canada) and is responsible for the first year design project. He also coordinates the complete design-implement project chain in the new program. He has many years of experience in the teaching of design and has research interests in the area of polymer processing.

Martine Gagnon coordinates the "Teamwork and leadership" course at Ecole Polytechnique Montreal (Canada) for the mechanical engineering department. She is affiliated to the CEC (Center for Complementary Studies). Her experience in team dynamics is built on multiple psychosocial consultations with international engineering project development teams.

Daniel Spooner is engineer-in-residence at Ecole Polytechnique Montreal (Canada) and teaches at the University of Montreal's School of Industrial Design. In the last 15 years, he has lead development teams of over 60 products for the transport, consumer, medical, and telecommunications industries. He also operates his own product design and engineering consulting firm involved in complex system design. His industrial experience provides a unique mentoring relationship to students in capstone projects. He also contributes actively to structure and build the CDIO capstone project initiatives at Ecole Polytechnique Montreal.

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Ricardo Camarero is Professor at École Polytechnique Montreal (Canada) and specializes in simulation-based design. He currently coordinates the activities of the Chair in Engineering Design at the MATI Montréal inter-faculty research centre. The Chair focuses on the application of information technologies in Engineering Design training and teaching.