PEER TUTORING IN A PROJECT-BASED COURSE

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Abstract – *In undergraduate engineering programs, design competency is mainly developed through project-based design courses. In such courses, a well framed practice is one of the best strategy to help students develop the ability to design solutions to complex, multifaceted and open-ended engineering problems. Nevertheless, supervising students, especially first-year students, requires a lot of effort and time. As the number of students increases, the task of closely supervising them becomes more difficult. Considering the small number of academic staff, peer tutors can provide a solution to the lack of resources. In addition to this, peer-tutoring is a very interesting pedagogical solution. In fact, the literature demonstrates that peer tutoring can benefit both students and tutors.*

Teaching assistants (TAs) have contributed in project based courses for a long time but there are not so many documented experiences about how to integrate peer-tutoring in a project-based design course or how to use fourth year students to tutor first year students.

In fall 2017, a peer-tutoring program (PTP) has been implemented in the first year multidisciplinary design course. Fourth-year engineering students with relevant design experience acted as tutors for teams of four or five students. The intention was to reduce the pressure on our professional staff, while maintaining the same quality level of supervision.

PTP assessment revealed that all stakeholders appreciated the experience. At low cost, it allowed more weekly hours of supervision and gave the professionals the possibility to perform tasks that only them can do. Although the impact of PTP on the quality of learning was not measured, the student level of satisfaction was very high.

Keywords: Project-based course, Peer-tutoring, Design competency, Teamwork.

1. INTRODUCTION

Engineering is a multifaceted profession in which design is a central activity. For that reason, design projects are a very good way to prepare students for the practice of professional engineering and allow the faculty to assess

graduate attributes. Given that design is a skill or behavior gained with experience[1] but also based on techniques and tools [2] students should be given the opportunity to gain various experiences throughout their education from courses in engineering science and also, and mainly from, project-oriented courses that specifically focus on design. The engineering programs offered by the Université du Québec à Rimouski (UQAR) integrate multidisciplinary project-based design courses (design workshops) throughout the curriculum. The teaching team assumes that design competency is composed of knowledge, know-how and social skills [3]; is an experiential skill developed through a self-reinforcing spiral process and well-supervised practice; needs the test of reality or prototyping to reveal the design strengths and weaknesses; and better develops by working on real needs and problems. The design component of the programs provides for a continuous integration of knowledge and design skills and cumulates 21 course credits distributed as follows: 3 in the first year, 3 in the second year, 6 in the third year and 9 in the fourth year. The design workshops, which are an important part of our program, begin with the "Engineering, Design and Communication" course in the first semester and is followed by a discipline-related CAD course in the second year. In the third year, students take a 6-credit project-based design course that over on a full academic year and requires students to complete a project with a client and to deliver a working prototype by the end of the year. Companies submit problems to the students who, must then design and build an adequate solution as part of a team, under the supervision of the engineering department's professors and professionals. In the fourth year, the capstone design project challenges students to push their own boundaries by working on projects that have a higher level of risk and complexity. The capstone design project courses run from September to April and include 9 credits. Students are grouped into teams and normally work with a client from the local industry or on their own project when they are in the process of starting a company.

Design projects are a very good way to prepare students for the professional practice of engineering. Nevertheless, supervising students, especially first-year students, requires a lot of effort. As the number of students increases,

the task of closely supervising them becomes more difficult. Given that the number of academic staff is relatively low, peer-tutoring can solve the problem; however, peer tutoring in itself is a very interesting pedagogical approach that can benefit students and tutors [3]. In the fall of 2017, a peer-tutoring program (PTP) was implemented in the first-year multidisciplinary design course. Fourth-year engineering students with relevant design experience acted as tutors for teams of four or five first-year students. The intention was to reduce the pressure on our professional staff, while maintaining or even improving the level and quality of the supervision offered to students.

After a brief literature review of peer tutoring applied in project-based courses, the paper describes how the approach was implemented in a freshman design course and presents the results of the assessment of the program. Finally, the last section concludes with some comments on the relevance and follow-up of the peer-tutoring program.

2. BRIEF LITERATURE REVIEW

2.1. Peer Tutoring (Definition)

Peer learning is a very old practice, “possibly as old as any form of collaborative or community action” [4]. In the academic sphere, it is common to learn by mutual help, with students working in small groups and asking each other questions. Peer learning exists everywhere in itself; however, in the 80s, in Anglo-Saxon countries, researchers, especially in the field of education, became interested in studying these learning interactions. They wanted to be able to reproduce and implement peer learning as a specific pedagogical strategy [4]. With the hopes of making higher education more accessible to everyone, peer tutoring was first developed to provide individual help to students facing hardships [5]. Peer tutoring then refers to a dyad of students where one is older and more experienced and helps the other to improve his skills on a particular subject; however, nowadays, and especially as part of the active learning approach, peer tutors are also used to facilitate learning among a group of students [5].

Project-based learning (PBL) is already based on tutoring principles. In fact, the instructor’s role is to tutor students and teach them how to learn. The instructor not only transmits knowledge, but is rather a learning mentor, facilitator, helper and mediator. The instructor must bring students to construct their own knowledge by working on a project with others [6].

In his sociocultural theory of learning [7], Vygotsky introduces the concept of the zone of proximal development (ZPD). The ZPD essentially represents the difference between what a learner can do without help and what he cannot do. The theory suggests that students learn more easily when they operate in the ZPD and when a more experienced person or peer helps a learner [8]. Vygotsky

postulates that peers who have just learned certain material guide tutees differently than experts, and therefore, use different language to discuss with the tutees. Consequently, one reason peer tutoring works well may be that tutors and tutees speak the same language, whereas teachers and students do not as much [8].

2.2. The Role of Peer Tutors in PBL

A peer tutor in a project-based learning approach acts more like a guide and facilitator than an expert. A tutor certainly needs to have good technical skills to ensure his or her credibility toward students. He or she must also have the ability to detect or anticipate problems [8]. The peer tutor is responsible for facilitating the learning process by providing information and bringing suggestions, asking questions and stimulating the teams [9-11]. The different roles can be summarized as follows:

- The peer tutor helps his team to respect the goals and timetable, keep the project concept simple and efficient, give feedback on the work done and secure students.
- The peer tutor asks questions to ensure the material is understood, stimulate reflection and help students solve problems.
- The peer tutor acts on the group dynamics to ensure a good climate and make sure the information is disseminated effectively within the team.
- The peer tutor observes his group and adapts his interventions to its specific needs.

The role is complex because the peer tutor needs to find the right balance between guidance and independence and results and processes. In addition, the role of the peer tutor is dual and to some extent, ambiguous. Indeed, a tutor is somewhat of an instructor, while the peer situation rests on informal relations and the ability to influence the team’s behavior. The peer tutor needs to find the right balance between his role as a peer, which is more the role of model, having essentially charismatic authority and informal relations, and his role of tutor, which focuses on the learning objectives and has some rational authority [5].

2.3. Peer Tutors - Selection and Training

When implementing a peer-tutoring program, tutor recruitment and training are two important elements that must be considered. According to literature, it appears that the tutors selected must have good social skills, be well-established within university life and have a good sense of responsibility and assertiveness. They should be good enough in the subject to stimulate questions and help the team find solutions to their problems [11-12]. Tutors should clearly not be selected only for their content expertise. As we have seen, their responsibilities go well beyond technical support. After the selection step, it is very important to prepare them to play their roles. Tutors need to be informed and trained about their roles and

responsibilities, the attitude to have with the group and some knowledge on the dynamics of a small task group [9]. Raucant also emphasizes the importance of supporting students during the semester and insists on the importance of informing students on the roles and limits of each one to avoid excessive expectations, disappointment and frustration.

2.4. Anticipated Costs and Benefits from a Peer-Tutoring Program

As previously seen, we all learn from our peers and tutoring is already a current, common and informal practice. So, why would organizations want to implement peer tutoring as a specific pedagogical method? What benefits can we expect from this practice? First, the formal structure of a peer-tutoring program creates relations between students of different years, which would not have been created alone. The small difference in status and age between tutors and students creates a climate of trust that helps students ask more questions, reveal their difficulties and errors and learn more from them [5, 6; 8-12]. As tutors are younger than instructors, their language is more similar to that of students, which helps the communication between them and promotes learning [4-9]. Another benefit of peer tutoring is that it is beneficial for both tutors and students. Bachelet [2] argues that peer tutoring strengthens the student's self-esteem and motivation and consequently reduces the drop-out rate. Braudit [9] also points out that, because they are models for the students, the self-esteem and self-confidence of the tutors are also boosted [13].

That said, implementing a peer-tutoring program is not free. Some research quotes that peer learning is "among the most cost-effective learning strategies" when other studies show more modest results [4]. Bachelet [5] questions the cost to implement this kind of pedagogical method and wonders if it is worth the cost. The author recognizes the many benefits of tutoring and learning for both the students and tutors, even if the benefits of the tutors are hard to evaluate; however, he questions if it is profitable because tutoring requires lots of time and human resources to select the tutors, train them, ensure their supervision and make documentation available. Bachelet also recognizes that teachers' efforts who implement this kind of project are often poorly recognized. He concludes by considering tutoring as an investment and bringing to our attention the importance in questioning the cost/benefit ratio, although, most studies on the economic effectiveness of peer tutoring agree about its profitability [5].

3. DESCRIPTION OF THE PEER-TUTORING PROGRAM

The "Engineering, Design and Communication" course is divided into three closely-related sections. The engineering section examines the various sides of the profession: fields of specialization, duties and

responsibilities of the engineer, and the role of the professional engineering association. The second section reviews the methodology used to develop technical products based on Ulrich's procedure [14]. Through teamwork and two projects, students must carry out the steps involved in developing a new product, from its design to the manufacturing of a prototype. The third section presents the fundamentals of interpersonal communication skills, efficient teamwork, technical writing and oral presentations. The six weekly hours are divided between instruction, methodology, explanations, exercises, team meeting, teamwork and peer tutor meeting.

Essentially, students must carry out a short and long project. The short project is a design competition between teams that takes place at the beginning of the year. The objective is to have students fully experience a design project while intuitively following the methodology used to develop a product. The long project has a greater scope. Students are divided into teams of four or five and spend approximately 11 weeks on the project, thus enabling them to go through all the steps involved in developing a product. Projects are evaluated based on progress reports, a final report, an oral presentation and the prototype.

In previous editions of the course, the professional teaching assistant (TA) tutored all student teams without the help of peer tutors. The task was too great for one person and did not leave enough time for a well-supervised design experience. In addition, the professional was not able to spend time with individual students in the workshops and design studio. As already mentioned, the intention behind the PTP was to reduce the pressure on our professional staff, while improving the quality of the supervision offered to students.

Overall, 38 students divided into 9 teams were part of the course. Six tutors participated in the PTP and three of them took care of two teams. The students had to design and build a Skittles-sorting machine using SolidWorks, an Arduino platform, a color sensor, actuators, a 3D printer and machine tools. The project lasted 11 weeks and the tutors met the teams every week for 45 minutes.

Tutors were selected based on design competency, social skills and the capacity and interest in helping other students. Two training sessions (three hours in total) were offered and the goal was to inform tutors on their roles and responsibilities as well as prepare them to face some possible difficulties and ethical problems. The tutors received a weekly email explaining that week's task list.

4. OBSERVATIONS AND ASSESSMENT OF THE PROGRAM

4.1. Methodology

The PTP assessment is based on the point of view of the tutors, students and our professional TA. It was conducted

to evaluate: the experience of being a tutor, a tutee and a professional in charge of the design workshop, the benefits of the program, the satisfaction of participants and the condition of its implementation. To this end, we used four instruments to collect information:

- A 1-hour focus group with the tutors at the end of the semester;
- An survey for tutors, with the Likert-scale and open-ended questions completed at the end of the semester;
- An online survey for students, with the Likert-scale and open-ended questions completed at the end of the semester;
- A written questionnaire, with three open-ended questions, completed by the professional TA of the department.

4.2. Results

We had an optimal response rate from tutors and the professional; however, the response rate for the student survey was only equal to 46%. The student survey was sent to students toward the end of the semester. At this time, students were still busy completing their project and courses. Reminders were sent at the beginning of the next term, but the response rate stayed relatively low.

4.2.1. The Experience

Tutors, students and professional perceptions about the PTP differ. Here is how each lived it.

Tutors:

Three tutors supported a single team and three tutors supported two teams. The tutors who had one team all said that afterwards, they could have tutored two teams and the load would still have been lower than what they thought. The tutors who had two teams all responded that the responsibility of following two teams was not too high and that they had time to do it within the deadline (2 x 45 minutes). According to the tutors, there are benefits in accompanying two teams. The tutor's experience is richer than with only one team. Indeed, the tutors have to cover more situations and more questions, which also benefit the teams.

We asked the tutors to categorize, from a list of eight functions and from the most to the least important, the different roles they played during the semester. Here is what we come up with: advisor, guide, facilitator, model, expert, supervisor, coach and leader. We believe that this list reflects the tasks and concrete actions taken by the tutors throughout the semester. The tutors' tasks focused on three main categories of activities: providing information, questioning and facilitating teamwork. The lists below present the most frequent tutor answers, from the survey and from the focus group in each category.

As an information provider, tutors:

- Give feedback on the work done and the reports submitted or to be submitted;

- Inform on the material and resources available;
- Remind about deadlines and help put the work that remains into perspective;
- Answer questions and give advice based on their own experience and knowledge;
- Help to understand the content, apply the process and solve problems;
- Help students to feel secure about the work to be done, the course requirements and even about the engineering program;
- Act preventively, anticipate problems that may arise and provide recommendations to students.

As a questioner, tutors question on:

- The progress of the project and the next steps;
- The work division among team members;
- The satisfaction of the work submitted and improvement possibilities;
- The things that were confusing and the students' understanding of the content;
- How to improve the process or overcome the difficulties?

As teamwork facilitator, tutors:

- Encourage and motivate the team by highlighting the progress, learning and successes;
- Help the team to communicate effectively;
- Help the team to organize itself, separate tasks between team members and set priorities;
- Help the team to manage conflicts, for example, by acting as a communication belt between team members when they do not talk to each other.

Tutors encountered some difficulties during the semester. For some of them, it was a challenge to explain technical issues to less advanced students. A tutor mentioned having difficulties with students who did not take his suggestions into account at all. Some tutors felt useless, for example, when the team was super independent and had no questions. There were also moments when tutors felt less comfortable in specific situations, especially when the dynamics of the group were weak, there was unfair participation among members, there was conflict in the group or a student was technically so good that the tutor did not feel comfortable advising him.

Students:

Like for the tutors, we asked the students to categorize, from a list of eight functions and from the most to the least important, the different roles the tutors played during the semester. Here is what we come up with: advisor, guide, coach, facilitator, expert, model, supervisor, leader. It is interesting to note that the first two and the last one are the same. According to the students, the list below corresponds to the tasks the tutors did often or always during the semester. We kept only the tasks for which 90% of students answered "often" or "always".

As an information provider, tutors:

- Refer the right people or resources when they are unable to answer.
- Give advice and answer questions about technical or theoretical aspects.
- Help to understand and clarify the content by giving explanations and examples.
- Give their opinion according to their experience and knowledge.

As a questioner, tutors:

- Make sure the stages of achievement and project schedule are understood and respected.
- Ask questions or make suggestions to help the team be more effective.

As a teamwork facilitator, tutors:

- Help the team take a step back from the project as a whole and put the steps already taken and those to come into perspective.
- Help the team set priorities.
- Encourage the team by highlighting its progress, learning and achievements.
- Are attentive to the challenges of the team.
- Adapt their interventions according to the specificities of the team.

Students told us about the tutors and their support, and how it differs from what other members of the faculty team offer. Here are some examples of what they told us:

“They are students just like us, so they can share their recent experience on different projects. This allows us to discuss the program from the point of view of another student.”

“Tutors are closer to our reality and their explanations are clear.”

“It was easier to communicate with them because they are also students.”

“They have a different way of addressing problems and bring diversity.”

“Tutors know what teachers want so they do not hesitate to give us advice to optimize our time and energy on aspects that they know are important.”

The professional

One of the goals of the PTP was to reduce the time the professional TA spends tutoring the teams. At the beginning of the project, the professional spent 3 hours meeting with the teams. She quickly realized it was not productive because the tutor was doing the same thing just before or after her. So, she adjusted herself, and at the end of the semester, she was only answering the questions tutors could not answer themselves. Instead of three hours, she needed only half an hour per week. She also noticed that the students did not visit her office as often as before.

4.2.2. Main Benefits

Benefits for the tutors

The main benefits for the tutors are the skills they perfected. Table 1 presents the averages calculated from the answers of the six tutors when we asked them to express their level of agreement or disagreement on a symmetric (1 for totally disagree and 4 for totally agree) scale for a series of statements.

Table 1: Benefits for tutors according to tutors

Statement	Average
Learn new content, tools, techniques or software.	1.3
Better understand engineering design concepts.	1.8
Improve my oral communication skills (active listening, questioning, clear expression of my thoughts).	3.5
Learn about teamwork and its winning conditions.	3.2
Develop skills in support and facilitation of teamwork.	3.5
Develop my ability to adapt to others.	3.0
Increase my self-confidence and assertiveness.	3.0
Develop social skills (ability to connect with students and demonstrate empathy for the students' difficulties).	3.2
Develop the ability to reflect on the results and process.	3.2

During the focus group, tutors mentioned that the experience had not allowed them to develop new technical skills, but has helped confirm some learning. For example, the tutoring experience led them to realize how good they were with the design and development process.

It appears that tutors especially developed their teamwork ability. They learned to motivate the team and be enthusiastic, but sometimes, tutors were more motivated and enthusiastic than the team. Tutors brought a point of view without forcing it and learned to work with a team whose members had different contributions and motivation levels. They also said that it was not always easy to keep the right distance between their role and friendship. At UQAR, cohorts are small and all students from the different cohorts and programs participate in extracurricular activities together.

While the greatest benefits for tutors were related to teamwork, they made it clear that they did not feel well equipped to deal with team problems or conflicts.

Benefits for the students:

The main benefits for the students are perfectly aligned with the course goals. Table 2 presents the averages calculated from the answers of the 17 students when we asked them to express their level of agreement or disagreement on a symmetric scale (1 for totally disagree and 4 for totally agree) about which impacts students felt the tutors had influenced.

Table2: Benefits for students according to students

Statement	Average
my motivation in the course	3
my motivation toward my engineering program	3.24
my participation in the team	3.06
my understanding of the course material	3.12
achievement of the course objectives	3.18
my understanding of the design methodology	3.59
the working atmosphere in the team	3.29

Other impacts

- The quality deliverables (reports, plans and specifications, prototype, etc.) were of better quality than in previous years. This is certainly not only due to the presence of the tutors, but probably contributed to it.
- Tutoring also contributed to better integration of freshmen students. The PTP allowed for the creation of links between fourth and first-year students. Tutors reported that first-year students asked questions not only during the official meeting with the team. This year, more first-year students participated in extracurricular activities (competitions, clubs, etc.), and we believe that the PTP may have played a role in this.
- The tutors were also models to students. In fact, students did not ask questions only about the project and the content, but also about the entire program. The program then becomes more accessible when you are in touch with more advanced students. Fourth-year students become colleagues, and the tutoring relation can persist in time.
- PTP gives the possibility to reach higher goals and lead students further. The project proposed was complex and the students performed beyond expectations. They developed competencies that well prepared them for the following sessions.

4.2.3. Level of Satisfaction

Overall, the tutors were very happy to have participated in the program. They all replied that if they had to do it again, they would volunteer again, and 5/6 said they would do this even on a voluntary basis.

What the tutors said they liked the most:

- Establish a relationship with the team and create links with the students. They had lots of fun interacting with the students; a tutor even said he had made new friends.
- Share their experience.
- Feel useful, for example, by telling teams that the skill and knowledge they were acquiring would be useful elsewhere in the program.

- Follow the process of the project design, especially because the challenge this year was interesting as it was a real one (a real and useful object to build), the project was complex and the level of difficulty was high.
- Develop teamwork skills.

What tutors said they liked the least:

- Help manage conflicts within the team.
- Work with students who were less motivated than the tutor himself.
- Feel useless sometimes.

How students express their satisfaction

Table 2 presents the average calculated from the answers of the 17 students when we asked them to express their level of agreement or disagreement in relation to their satisfaction on a symmetric scale (1 for totally disagree and 4 for totally agree).

Table 3: Student satisfaction

Statement	Average
Tutor helped my team.	3.47
Tutor helped my learning on an individual scale.	3.12
I am satisfied with this tutoring experience.	3.59
I believe that the tutoring program is important and must be maintained.	3.82

All students believe that this program must be maintained over time and found it motivating to talk to more advanced students and share experiences with them. One student also mentioned his interest in peer tutoring in more theoretical courses.

Satisfaction of the professional TA and organization

For a program that was in its first year of implementation, the engineering department is satisfied. The professional TA was used to supervising the different teams but not anymore. She is now in charge of supervising the tutors and is more available for provide higher-level technical support. The professional is impressed by the tutors' commitment toward students.

5. DISCUSSION AND OBSERVATIONS

The TPP has clearly been appreciated by all stakeholders. The cost of the operation is relatively low. Six tutors were hired for a total of 90 hours. The PTP allowed for more coaching of the student teams and freed the professional, which gave her the opportunity to perform tasks that only she can do.

Concerning the experience lived, the abundant information collected will be useful to improve the PTP. We now know the difficulties the stakeholders have experienced. They told us they want to be better guided in terms of teamwork management. We also noted the feeling of uselessness sometimes present among the tutors. Some

teams performed very well because some members already had skills that were directly related to the project. We will take this into account when we improve our PTP.

Tutors and students agree about the tutor role. They consider that the two most important functions of the tutor are advisor and guide. There is also a match between what the tutors say they have done and what the students say the tutors have done. Moreover, the way things worked out is what the literature reports for similar experiences.

Regarding the benefits of tutoring for students, it is difficult to evaluate what is specifically attributable to the tutors, but the assessment reveals the influence of tutors on different academic spheres. For example, the quality of the deliverables was better this year and there were more freshmen involved in extracurricular activities this year than in previous years. We are curious about how much is attributable to the tutoring program.

6. PERSPECTIVE OF IMPROVEMENT

During the implementation phase of the PTP, the workload of the professional TA was not reduced, but after a few weeks, she stopped meeting the team and focused on other tasks. When questioning the students and tutors about the impact of the program, the answers were unanimous: the PTP meets the expectations and the efforts paid off; however, the teaching team believes that tutors could have more impact on teamwork and team spirit if they were better prepared. Although the impact of the PTP on the quality of learning was not measured, the students' level of satisfaction increased significantly compared to the last time the course was given.

From the experience, 4 main areas of improvement were put forth:

- Enhance tutor training - Tutors need to be better trained on teamwork management and on how to have more impact on the quality of communication among team members. The training should include notions on conflict resolution and prepare tutors to influence the integration and participation of all members.
- Develop a guide for tutors – Tutors are very busy and hard to bring together. We will develop a short guide to help them to remember what to do and what to check during a meeting, for each design phase.
- Improve tutor support - Not all teams are easy to guide. Some need very little supervision while others need a lot more. Sensitive issues can also arise among the teams. For these reasons, we will implement at least one co-development workshop so that everyone can express the difficulties encountered and help identify solutions.
- Impact measurement– Assessment shows a high level of satisfaction and impacts on tutors and students. We want to improve the evaluation process in order to have more significant data on student learning.

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