

Bringing First-year Engineering Students to Reflect on their Learning Strategies

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Abstract

This paper reports on a qualitative appraisal of the ability of first-year engineering students to engage in a metacognitive process about their learning strategies. At the beginning of the semester, texts on learning strategies, reading, concept mapping, emotional competencies, change and stress were distributed to each student and discussed in the classroom. We emphasized the importance for students not only to monitor their performance during the semester but also to look back on their learning strategies and, if necessary, to improve them. To that end, we asked students to periodically write in a personal learning journal their thoughts about their learning strategies. As an incentive, we told them that, as one of their final exams, they would have to write a 7 to 10-page essay about their learning strategies. They were also informed that they would be graded according to their ability to analyse their strategies, whether these strategies were optimal or not. Results of a preliminary analysis of these essays confirm that it is possible to bring first-year engineering students to reflect on their learning strategies.

1- Introduction

The Department of Electrical Engineering and Computer Engineering of the Université de Sherbrooke, Québec, Canada, has totally redesigned its Electrical Engineering and Computer Engineering Co-operative programs. The first semester of these new programs was offered for the first time in September 2001 to 167 freshmen engineering students. These new curricula are founded on a competency-based framework, following an original learning approach that combines Problem-based and Project-based Learning called APPI (French acronym for « **A**pprentissage par **P**roblèmes et par **P**rojets en **I**ngénierie »)¹. There are no more lectures. Instead, on a repetitive two-week schedule, a small group of nominally 12 students meets twice with a tutor. During the first meeting, students try to solve a given problem with the knowledge they have already acquired and identify what new knowledge is required to fully solve it. Then, they go on to studying and applying their new knowledge. To help them organize their knowledge, we ask them to draw concept maps and procedural maps. During the second meeting, the problem is summarised and solved, using the new knowledge acquired during the first week. As support, students can use only maps they have elaborated during their studies. They have the permission to modify their maps, if necessary, during the meeting, according to what they hear from other students and to what is validated by the tutor. At the end of that second meeting, a fifteen-minute period is set aside to give students an opportunity to exchange on their learning strategies. Students are invited to record their thoughts in their learning journal once at home.

Before leaving, students give their maps to the tutor who reviews each one, annotates it and returns it to students at the next meeting. No mark is granted for such maps.

Each week, there is a three-hour period dedicated to procedural training (problem-solving sessions) during which students are prompted to use procedural maps they have elaborated, or any other document, to solve assigned problems. Typically, students work by themselves or in groups on a given problem for a certain period of time. Afterwards a student is invited to go to the front of the class and present his or her solution on the blackboard. Other students can ask questions and are invited by the supervisor to validate or invalidate the solution presented.

Each week, there is also another three-hour period dedicated to laboratory training. In the first week of the two-week schedule, students familiarize themselves with new concepts they have to master in order to solve the problem they were assigned during the first meeting with a tutor. In the second week, they materialize and test the theoretical solution they found. A written report is required and is marked.

Each week, a two-hour supervised period is dedicated to the semester-long design project. It is within those periods that workshops on different topics are sporadically held throughout the semester. These include workshops on change, problem-solving process, active listening, team consolidation, brainstorming, arguing, feedback and conflict resolution, stress management and oral presentation.

Notwithstanding the fact that we have completely redesigned our curricula based on competencies and problem-based learning which integrate, for each problem, parts of contents of more than one traditional course, the students must still register, as usual, to a given number of courses at each semester. This comes from the fact that we must respect the established rules of the Université de Sherbrooke which stipulate that in each semester, a student must register in a given number of courses and a mark must be given to each of them at the end of the semester. To solve that problem, and still adhere to the competency-based and problem-based learning approach, we defined, for each course, some elements of competency which, when put together form the competencies to be achieved for that semester (see Appendix 1 for a listing of the first semester courses and elements of competency). Among the end-of-program competencies to be mastered by every graduating students, there is an intrapersonal competency that can be formulated as follows :

« To practice self-assessment, that is, to view things in their proper perspective, to evaluate the situation, to evaluate one's limitations, one's need of life-long learning and, when needed, to resort to external expertise ».

That competency, like most of other end-of-program competencies, should be built up gradually each semester. For the first semester, we ask first-year students to practise on the following elements :

- Develop autonomy in learning
- Manage one's time efficiently
- Adapt oneself to change
- Manage stress
- Cast a critical eye on one's learnings

We emphasized the importance for students not only to monitor their performance during the semester but also to look back on their learning strategies and, if necessary, to improve them. To that end, we asked students to periodically write in a personal learning journal their thoughts about their learning strategies. As an incentive, we told them that, as one of their final exams, they would have to write a 7 to 10-page essay about their learning strategies based on the content of their learning journal. They were also informed that they would be graded according to their ability to analyse their strategies, whether these strategies were optimal or not. The essay accounts for 20% of the grade for course GEN-100 and 20% for course GEN-110.

2- Background

We anticipated that most students would be thrown off balance by our new problem-based learning environment for which the traditional teacher and student roles are interchanged. Students must assume increasing responsibility for their learning as small group meetings with a supportive tutor interlaced with self-directed learning periods are substituted for lectures. As mentioned by Huba and Freed³, « ... when we shift paradigms and move from teacher-centered to student-centered strategies and approaches, we must help our students shift paradigms as well. Students who expect us to lecture and impart information may not view other strategies as « real teaching ». They may question or invest minimal energy in small or large group discussions or in applications ... because they view these activities as fillers that take up time until real teaching begins ». Students need support to develop a new paradigm about learning and to become reflective thinkers. We use three kinds of support : Texts on learning strategies, small group discussions and the use of a learning journal in which students are invited to write their thoughts. As mentioned by Jolly and Radcliffe⁴, « While training in reflexion may be achieved through a variety of techniques, the act of transferring thought into words may lead to higher levels of abstraction and analysis, thus rendering the reflective journal a particularly appropriate tool for the development of such skills. »

Furthermore, there is a good chance that many of the learning strategies students have developed until now and which brought them success in the past would be inappropriate for that new learning context and for the heavier than normal (considered from their past experiences) workload they have to carry. A review of the literature on learning journal by Moon⁵ pointed out that writing, among other things, is a good tool to enable learners to understand their own learning process, to deepen the quality of learning and to support behaviour change.

3- Texts on learning strategies

In order to help students identify what we mean by « learning strategies », a text on learning strategies as others on reading, concept mapping, emotional competencies, change and stress were distributed to each student and discussed in the classroom at the beginning of the semester. Credit must be given here to Boulet, Savoie-Zajc and Chevrier for their book² from which we adapted a large part of our tables on learning strategies.

We define a learning strategy as an activity carried out by a learner during learning in order to facilitate the acquisition and memorization of new knowledge and its subsequent recall and application. As suggested by Saint-Pierre⁶, we have divided learning strategies into the four following groups : cognitive strategies, metacognitive strategies, resource management strategies and affective strategies.

3.1- Cognitive strategies

After a brief description of the three categories of knowledge - namely declarative (the what), procedural (the how) and conditional (the when) – as recognized in cognitive psychology⁷, we present to students, as shown in table 1 (adapted from Boulet²), the related cognitive strategies. We draw students' attention to reading and mapping strategies through two short separate documents. The construction steps of a concept map follow those proposed by Novak⁸ whereas those of an heuristic map come from Buzan⁹.

3.2- Metacognitive strategies

Metacognition refers to two separate but related elements : the learner's knowledge and the consciousness of his own cognitive process and the learner's ability to manage it. According to Flavell¹⁰, we classify metacognitive knowledge into three types : intrapersonal knowledge, interpersonal knowledge and universal general knowledge on the human cognitive process

According to Brown¹¹, the management of the learner's cognitive process takes place through three possible groups of metacognitive strategies, that is those concerning planning, control and regulation. We present some strategies for each of the three groups (see Table 2 (adapted from Boulet²)). Those related to control and regulation were identified by Kluwe¹².

As part of universal general knowledge on the human cognitive process, we present a separate document on the brain and on information processing. Most of the material presented on the brain are adapted from Jensen¹³ whereas the architectural brain information processing model shown in figure 1 is adapted from Villeneuve¹⁴ and Gagné¹⁵.

3.3- Resource management strategies

Resource management strategies are used by the learner to adapt his or her environment to his or her particular needs or to adapt himself or herself to the existing environment. There are three kinds of resources : temporal, material and human. As shown in table 3 (adapted from Boulet²), we present students with strategies a learner can use to manage and organize temporal and material resources and others which can be used to take advantage of the support of human resources.

3.4- Affective strategies

As mentioned by Goleman¹⁶, the learner's ability to learn is a direct function of his or her capacity to give himself or herself up entirely to a subject, that is to his or her enthusiasm, which is the supreme principle to motivation. If a learner does not care, his or her feelings and emotions can stop, or at least significantly slow down his or her learnings. The learner must therefore use appropriate affective strategies in order to create a propitious psychological learning context.

As shown in table 4 (adapted from Boulet²), we present students with three types of affective strategies, namely those used to establish and maintain one's motivation, those used to maintain one's concentration and those used for stress control.

Table 1
Cognitive Strategies

| Declarative knowledge | Rote-mode | Meaningful mode |
|--------------------------------|--|--|
| Repetition strategies | - Repetition | - Selective note taking - Underlining - Framing - Shading |
| Elaboration strategies | - Mnemonics | - Personal notes - Paraphrase - Summary - Analogies - Formulation of questions - Identification of implications - Examples |
| Organisation strategies | - Lists - Sets - Classes - Groups | - Table of content - Plans of actions - Hierarchical networks - Maps |

| Procedural knowledge | Meaningful mode |
|---|--|
| Knowledge compilation Strategies | - Practice parts of the procedure - Practice the global procedure - Compare performance to that of a reference model |

| Conditional knowledge | Meaningful mode |
|----------------------------------|--|
| Generalization strategies | - Identify examples - Invent examples - Find similarities |
| Discrimination strategies | - Identify counter-examples - Invent counter-examples - Find differences |

Table 2
Metacognitive strategies

| | |
|------------------------------|--|
| Planning strategies | <ul style="list-style-type: none"> - Set goals - Gauge the required level of information processing - Forecast the number and the type of processing - Predict steps to follow - Forecast probability of success - Forecast the required time and its allocation |
| Control strategies | <ul style="list-style-type: none"> - Classification : identify the type of cognitive activity - Checking : be aware of one's progress and results - Evaluation : evaluate the quality and the efficiency of one's cognitive activities - Prediction : anticipate possible solution alternatives and expected results |
| Regulation strategies | <ul style="list-style-type: none"> - Regulate the processing ability - Regulate the topic processed - Regulate the strength of the processing - Regulate the speed of the processing |

Table 3
Resource management strategies

| | |
|---|---|
| Strategies for managing temporal resources | <ul style="list-style-type: none"> - Plan work and study schedules - Set objectives within the required time - Set up work and study plans taking time into account |
| Strategies for organizing and managing material resources and the studying environment | <ul style="list-style-type: none"> - Identify the available and appropriate materials and resources - Adopt an efficient and personalized management of materials and resources |
| Strategies for taking advantage of the support of available human resources | <ul style="list-style-type: none"> - Identify the available resources - Ask for help and support from available resources |

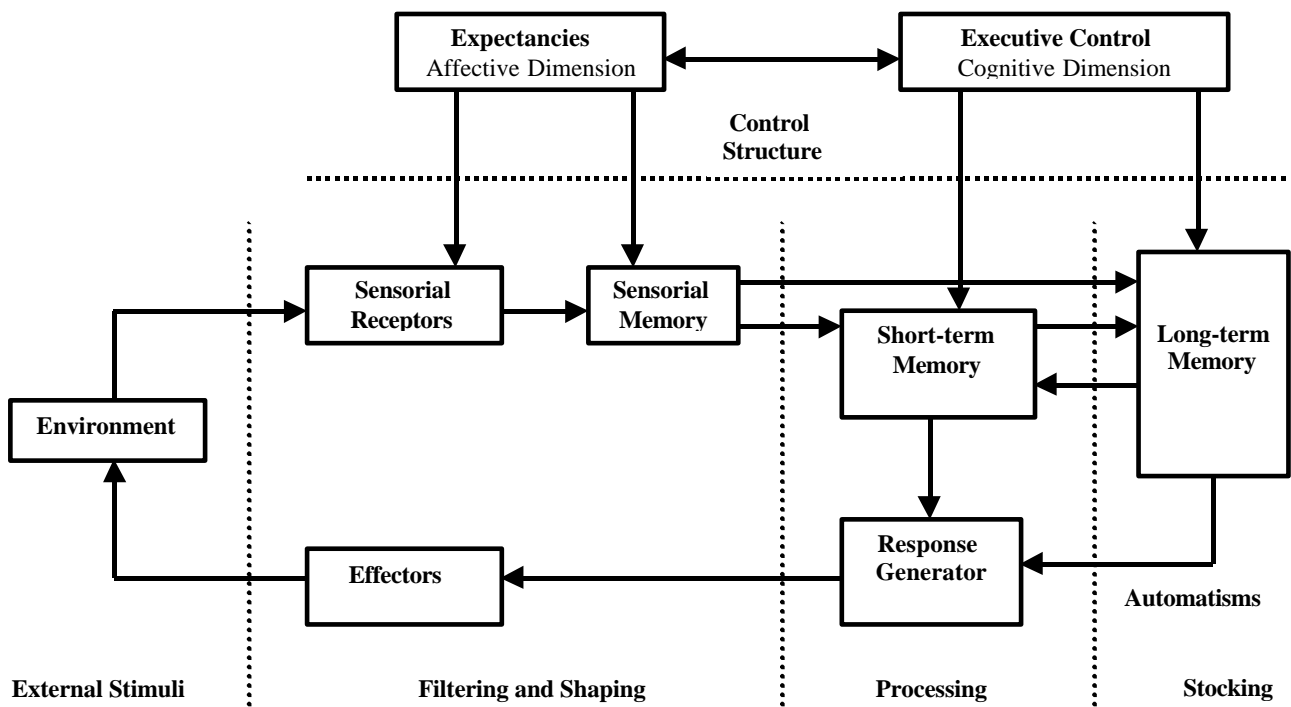


Figure 1 Brain Information Processing Model

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Table 4
Affective strategies

| | |
|--|--|
| Strategies to build and maintain motivation | <ul style="list-style-type: none"> - Establish personal performance objectives - Set up a reward system |
| Concentration holding Strategies | <ul style="list-style-type: none"> - Get rid of diversions - Create a sane climate for work and study |
| Stress control strategies | <ul style="list-style-type: none"> - Identify and use relaxation techniques - Identify and use stress reduction techniques |

We give students a separate document related to the stress and its management. It presents, from a psychological and a biological points of view, the nature of positive and negative stress and the psychological, physical and behavioural symptoms of negative stress (adapted from Pépin¹⁷). It also points out that it is possible to reduce stress by acquiring some specific competencies which give the learner the feeling that he or she is in control of a situation. We refer here to problem solving, time management and emotional competencies.

To help students acquiring competencies in problem solving, we first define what a problem is and then present a general seven-step problem-solving process.

As change often induces stress, we also hand out a document dealing with change and resistance to change. We first make a distinction between a change, that is the external event, and a transition, that is the internal personal response to that change. Then, following Bridge¹⁸ and Roberge¹⁹, we present the four phases of the adaptation-to-change process using the comparison with the four seasons.

4 - Final exam

As one of their final exams, students had to write with a text editor a 7 to 10-page essay. The instructions given were the following:

« You must evaluate your own cognitive, metacognitive, emotional and resource management strategies. That evaluation must disclose not only the knowledge you have of your strategies but also what controls you exercise on them with your planning, your monitoring in action, your self-criticism of progress made and, if applicable, the changes you made to your strategies. The purpose of that essay is not to please the professor but to demonstrate that you are able to cast a critical eye and a valid judgment on yourself. The essay must be divided into the following five sections : adaptation to change and stress management, autonomous learning, time management, critical eye casting on your own learning during the semester, your vision of the profession of electrical engineering or of computer engineering. »

It was a one-day long take-home exam. We told students that they had to show professionalism and integrity by writing the essay themselves and that they had to confirm at the end of their essay that they had adhered to this code of honor.

5 – The results

All of the 167 students wrote the essay. Only 7 omitted to sign their essay and confirm that they had written it by themselves. 44 students wrote only 5 to 6 ½ pages out of the required 7 to 10 pages ; one wrote only 3 ½ pages and another one, only 2 ½ pages.

Only 24 students made a direct reference to their learning journal. Although we cannot conclude that others did not write a learning journal during the semester, we can surely acknowledge that we did not put enough emphasis on the learning journal at the beginning and during the semester. We should have given students more support by responding adequately to a student comment heard frequently during the semester to the effect that they were not sure what they should write in their journal. For those who did write a journal, it seems that the activity was beneficial.

From what we read, we can say that, with two exceptions, all students who wrote the end of semester essay have succeeded, in one way or other, in reflecting on their learning strategies. It seems that most of them made it during the semester whether they wrote or not a learning journal. In what follows, we give a brief qualitative analysis of what we found in essays related to learning strategies. When appropriate, we use a typical quote to represent what was reported by many students.

5.1 – Cognitive strategies

Among the cognitive strategies listed in table 1, those most often cited by students are : underlining, summaries, maps and questions formulation. Many students report that, owing to the large quantity of reading they had to do and the complexity of contents, they had to make the transition from rote-mode, that is reading and remembering as much as possible, to meaningful mode , that is underlining and summarizing.

Only about one fifth of students reported that drawing concept maps was beneficial to them. The others point out that such maps were very hard to do, that they did not use them in studying and that they did them only because they had to submit them to their tutor. Here are some typical comments :

*« It has come to me that maps allow me to know what topics I master well, less or not at all. »
M-J. B.*

« I have decided to no longer trust my concept maps because they are too fuzzy and not usefull in my study. » C. R.

« I have chosen to make summaries instead of concept maps as it what suggested at the beginning of the semester because, for me, summaries stay longer in my memory and are easier to understand. » R. F.

With regard to the questions formulation strategy, about twenty students report that they use it. By itself, the problem-based learning approach does not require team working from the students. Each student must study and solve by himself each problem and each student is individually evaluated once every two weeks. However students must share their solutions because they work in teams in the labs during the experimental validation of the solution to each problem and on the semester-long project ... both activities requiring a written team report. It therefore comes out that many students also used team work as a learning strategy. The following comments illustrate that :

« The mere fact of asking questions to a team-mate or responding to a question requires attention and this helps me because I have never really studied before and it is very difficult for me to remain concentrated. Studying with a team-mate necessitates a sustained attention from me. Furthermore, it happens sometimes that I must explain a part of the subject matter to my team-mate. I consider this as a true chance because, when I explain it to him, I don't only help him to better understand but I also help myself. Indeed, to explain a notion, I must previously have understood and acquired it. I think it is the best way to review the subject matter because I see immediately if my explanations are clear or not. » J-L. R-B.

« I have developed many techniques to validate my knowledge. One efficient way... is with my other team-mates. Asking questions or trying to enlighten others inform us on our comprehension of the subject. » P. F.

At this point, we could estimate that about 90% of students have the feeling that they have succeeded to learn by themselves. However, for those ten percent of students who have not succeeded in self-learning, it is clear that they did not develop a new paradigm about learning, as can be concluded from the following typical quotes :

« I have found it so demanding to learn and understand by reading. I would appreciate that someone teach me and explain me the content of those books. ... It would absolutely require coaching to guide us in our studies. Self-learning is not given to everybody with the same easiness. Maybe it is to soon in our training to ask us so much. » L-D. H.

« I am a person who needs someone to summarize the subject, I need someone who explains me in detail, who gives me examples. It is difficult for a person like me to learn by myself. » T. S.

5.2 – Metacognitive strategies

Among the metacognitive strategies listed in table 2, those most often cited by students are : be aware of one's progress and results, evaluate the quality and the efficiency of one's cognitive activities. As a preliminary analysis, we ascribe that result to the fact that students have an exam once every two weeks (or each week if we consider the formative exam) instead of mid-term exams and final exams. They therefore have more frequent feedbacks which allow them to find out whether their strategies were appropriate or not. Here are some typical quotes :

« At the beginning of the semester, I did not solve the drill problems ; I thought that it was not necessary. I preferred reading and studying. ... However, I soon realized that the procedural practice was very important for exams. I therefore began to solve drill problems and the further I got into the semester, the more it was useful for my exams. » J-F. A.

« I soon realized that in addition to making me loose my time reading and memorizing were not really efficient. » D. J.

« The first times I drew maps I considered that I was loosing my time. But, with time, I realized that if I was able to make a structured map including the majority of concepts, it meant that I had understood the subject. M. C.

5.3 – Ressource management strategies

Among the resource management strategies listed in table 3, those most often cited by students were: plan work and study schedule, ask for help and support from available resources. This is not surprising if we consider that students perceive they have an heavier than normal workload. Here are some typical quotes :

« At the beginning of the semester I had a lot of difficulty with the workload. This resulted from the fact that I had no schedule and no listing of what I had to do. Considering the large amount of documentation to manage, the use of a listing was mandatory : all the stuff to study and the classification of the documentation. It was the first step toward good time management. Later, I added a time variable to my planning. With that method, it was much easier to manage my time. » G. M.

« ... I am fully aware of the deficiency of my personal time management and I know that it is a point I must work on. » F. P.

« Another thing I learned during the semester is that if I want to go through, I cannot do that alone. It is with the cooperation and the support of my colleagues and the one I will give to them at the appropriate time, that I will graduate in four years. It is also the image of the present labor market : everything is now done in team. » N. J.

5.4 – Affective strategies

Among the affective strategies listed in table 4, those often cited by students were : set up a reward system, get rid of diversions, create a sane climate for work and study, identify and use stress reduction and relaxation techniques. Here are some typical quotes :

« During the semester, it often happened that I lost motivation, considering the heavy workload and results poorer than the expected ones. One reason to explain that was that I did not give myself the permission to take time to take a break. During the last weeks of the semester I took more time for myself and I noticed that it made me feel more motivated and I performed better. » N. P.

« When I was in high school I listened to music when studying. At the beginning of the semester, I still did not bring with me my stereo so I had to do without, so realising that my study was more productive. » J-F. D.

« I realized that another good means to increase my concentration was a clean surrounding environment. That may sound ridiculous but when my room is in disorder it has an effect on my disposition to work. » J. B.

Some students reported that they used their learning journal as a stress reduction technique :

« After four weeks, the stress began to build up and it was imperative to find a way to calm down. I began to take seriously the advice of writing a learning journal. When I felt the need, that is once or twice a week, I wrote about my feelings, about what was going well, about what needed to be improved in my learning. And it was beneficial. By having landmarks, points to be improved, my strengths, I felt greatly secured. This journal allowed me to have a clear vision and to realize that I was on the right track. » P.L.

« Writing a learning journal ... allows me to write down my emotions, good or bad. Numerous times, my journal saved my team-mates from my frustration ! Indeed, I used my journal many times to transcribe my anger in connection with team work. Most of the time, this emotional charge on paper was the first step toward the application of efficient actions, such as the application of conflict resolution methods. The journal also helped me to motivate myself. The reasons for my lack of motivation being clearly written, I was able to see what options were available to me. » P-A. S.

6 - Conclusion

We conclude that it is possible to bring almost every first-year engineering student to reflect on his or her learning strategies. Three means were tried : a personal learning journal, an end-of-semester essay and reference documents.

We have the feeling that most students did not write a learning journal. We recognize that we did not sufficiently stress the importance of the personal learning journal and haven't guided students well enough in the writing of their journals. We only gave them oral suggestions ; no written document on how to write a journal and why it should be written was given to them at the beginning of the semester. Next year, at least, a specific text on that subject will be added to our documentation and given to students at the beginning of the semester.

The end-of-semester essay was a great success. One part of that success may be attributed to the fact that the essay was graded whereas the personal learning journal was not. However, we can conclude that, at the end of the semester, almost all of our first-year engineering students can cast a critical eye on their learning and can write an essay to prove that point. The end-of-semester essay seems to be an efficient way to bring students to reflect, as can be concluded from those typical quotes :

« One of the important points for my introspection is without any doubt, that essay... In my opinion, it is a unique chance offered to me to evaluate what I have done, and especially how I did it. It is the climax of my metacognitive activity of the semester. » J-L. R-B.

« That essay, like my semester, made me ask myself questions which had never come to me before. I have discovered some of my strengths, some of my weaknesses and new ways of doing things. It is with this new perspective that I would evaluate my progress in education in the future. » J-F. B.

« If that essay allows you to learn more on the difficulties faced by a first-semester student, it gave me the opportunity to do a retrospect of my semester, and it is from this point of view that I value that work. I was not able to realize, without the writing of that essay, that it was an unforgettable experience. » D. G.

« *I find that the steps necessary to write that essay were very interesting, even if I thought at the beginning, like many others, that it would lead nowhere. It allowed me to do an introspection to determine what changes I have lived through during the last four months and how I can adapt to living with those changes and what were the learning strategies I used and how I managed the stress....* » M-A. V.

Finally, through the reading of the essays, there are many signs indicating that, during the semester, many students used the written materials presented in section 3 to learn how to learn by themselves. Surely, some used it only at the end of the semester to help them write the essay. In spite of that, they are honest enough to acknowledge it:

« *... I realize that the documentation handed out at the beginning of the semester is worth its weight in gold. I am angry at myself for not having assimilated it more deeply ; it would have given me a much easier task.* »

In order to show our September 2002 first-year engineering students the beneficial effect of reflecting and writing a learning journal, we plan to include in next year's handouts many of the September 2001 students' comments presented in this paper.

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Appendix 1

First-Semester Courses and Elements of Competency

GEN 100 Problem-Solving Process in Engineering 3 credits

Elements of competency :

- a) Apply each step of the engineering design process
- b) Apply each step of the engineering problem-solving process
- c) Adapt oneself to change, manage stress and acquire skills to develop those two competencies
- d) Explain and justify clearly the utility and the importance of team work for engineers
- e) Use efficiently the basic tools of team work
- f) Develop autonomy in learning
- g) Manage one's time efficiently
- h) Cast a critical eye on one's learning strategies
- i) Describe the electrical and the computer engineering professions

GEN 110 Communication and Information in Engineering 3 credits

Elements of competency :

- a) Communicate verbally, graphically and by writing, according to given requirements and using appropriate tools.
- b) Read accurately electrical and electro-mechanical schematics
- c) Communicate efficiently within a team
- d) Search for information using appropriate tools and sources
- e) Use with ease the available computer facilities

GEN 120 Linear Algebra and Differential Equations 3 credits

Elements of competency :

- a) Recognize the presence of a linear system of algebraic equations or a system of constant-coefficient linear differential equations during a problem-solving process and,
- b) Solve those systems of equations, by hand or simulation, depending on their complexity.
- c) Predict the expected order of magnitude of a result and detect gross computation errors
- d) Give a physical meaning to equations and to their solutions by referring back to the engineering problem from which they originate.

GEN 130 Electrical Components and Circuits 3 credits

Elements of competency :

- a) Explain the principle of operation of usual electronic components with regard to fundamental laws of electricity and electromagnetism
- b) Model a physical electric circuit with an electrical circuit schematic
- c) Apply electrical circuit laws to build the mathematical model of a circuit
- d) Determine, by hand calculation and simulation, the transient and steady-state time responses of first and second-order linear circuits submitted to a step input.
- e) Become handy in soldering and assembling electromechanical components
- f) Generate and explain experimental data obtained with standard laboratory equipments
- g) Use a transistor in switching mode to activate actuators

GEN 140 Programming and Microprocessor 3 credits

Elements of competency :

- a) Write a short C/C++ program using a unique-user development system
- b) Program a microprocessor for data acquisition and decision making tasks.