APPLYING RESEARCH METHODOLOGY TO UNDERGRADUATE COURSES

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Abstract - Students at the School of Engineering of the University of Buenos Aires are requested, in their senior years from a six year program, to produce some research related activities and to write a Thesis. Thesis works are regularly procrastinated because of reasons such as a highly unstructured (and thus unfamiliar) activity, lack of background on how to perform research, workplace pressure or lack of time. In addition, there is a social appreciation of research as a highly difficult task reserved only to Nobel Prize winners. Also research activities have been considered as being very different from the daily engineer’s work. In one of our courses, students get the big picture of concurrent programming fundamentals and its associated caveats and then, they must cover a more real world approach. We decided to guide them in some information collecting tasks, asking students to use some of the approaches in real world problems and comparing them by developing figures of merit. In the process we found ourselves developing in our students skills which seems to be more transferable than detail level programming skills and more in line with modern software industry requirement.

Index Terms - Active learning, Concurrent programming, Undergraduate research experience, writing.

INTRODUCTION

A thesis is an unknown work for students. It is different from what they have been asked before. One of the main difficulties of a written thesis work is its apparent lack of structure. Thesis seems to be unrelated with classical problem solving, multiple choice grading, programming assignments and related activities students are used to regard as their duties.

However, research activities are not that different from self-study activities. They are also not that different from active learning techniques that are beginning to be seen more frequently in the classroom [1].

NSF report 96-139 states that it is important for students “to learn not only science facts but, just as important, the methods and processes of research, ... , how to make informed judgments...” [2]. It is difficult not to agree with the preceding statement. But the desired underlined skill of making informed judgments does not stem automatically from exposing students to reading activities, asking them for writing or promoting an active attitude in lectures. This and other techniques lead to a meaningful and perhaps reflective learning, but the scale of the activities done in the classroom is several orders of magnitude inferior than the scale of a written thesis work, and some order of magnitude more structured than it.

In this paper we expose our experience in leading undergraduate students through a sections of a thesis work. In fact, the final assignment we ask them can be further developed to become a full-blown thesis after some time of serious work, but is limited in time, size and contents in a way that allows us to follow its progress. To meet our expectations, the assignment is started after the midterm, must deal with the different stages of a research work, and ends with all the elements asked for a thesis at the School of Engineers of the University of Buenos Aires. These are: a well written report, the development of some thing or process, a Viva Voce interview with examiners with different familiarity with the work's subject, and a public presentation. The work has to exhibit an understanding of theoretical foundations of the developed work, and must show how theory guides and explains the used engineering practice. We do not ask for originality in this assignment.

RESEARCH RELATED ASSIGNMENTS

A study about the state of undergraduate teaching in American Research Universities, states that "many students graduate having accumulated whatever number of courses is required, but still lacking a coherent body of knowledge or any inkling as to how one sort of information might relate to others" [3]. The situation is even worse in Argentina, where very few universities can exhibit a "critical mass" of full time professors to attempt serious research work.

Several educators think the answer lies in developing a more active attitude and a more involved participation of students, with themselves, with the profession they chose and with their mates, professors and the institution facilities such as Labs and Libraries. Therefore, research related assignments are becoming a commonplace in undergraduate study. They have been reported as an excellent way to promote an active involvement of students, to enhance communication skills and also to develop a sense of ethics and respect for the other's work. These activities are also the Blueprint the Commission that wrote the above mentioned study asks for.

In [4] the author exposes a conference scheduled for a physics course, where students must experience all aspects of preparing a professional paper for publication, including a presentation. This strategy allows students to choose a topic

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that interests them, encouraging going for further detail than allowed during class time. This approach is further followed in [5] as “a technique for infusing writing in the courses”.

Writing-to-learn strategies in the Science, Math, Engineering & Technologies (SME&T) realm are evolving to make them more motivating to students. Writing has been proved as a superb strategy to discover misconceptions and to assist students to articulate their thoughts. We used writing previously in combination with a learning style approach with success [6]. Some of the students enrolled in the concurrency course were exposed to these previous experiences.

It is also asked for soft skills to be present in our graduates. These are skills that can be transferred from one realm to other and are indispensable for a multidisciplinary activity, as required by today's Science and Technology. There is a stress between the thesis as an individual work and the research as a collective endeavor. Networking with peers seems to be the answer to this stress, and one of the aims of the research related activities is to create a sense of community with peers over the world.

**CONCURRENT PROGRAMMING**

Concurrent Programming is a broad area, with many different views and plenty of details. It has been defined as the intersection of the support of synchronization for concurrently executing cooperating processes in an Operating System, and the programming styles of Parallel Processing.

In our case, the subject evolved in the same way, from a special course in Operating Systems to a broader range of topics and the selection of what to include and what to let outside was always difficult and unsatisfactory. The subject is a tricky one, where things seem to be easily understood until a hands-on problem is asked. And when someone wants to go into practice, it is easy to get lost in an infinite number of tiny details. In a previous work we developed an active way to engage students in the general questions of Concurrent Programming avoiding its deceptively apparent easiness [7].

On the other hand, theoretical background of Concurrent Programming makes a heavy use of Math and is not specially suited as a guiding tool. It is well suited to explain working and not working solutions, for things like a post development analysis. Some authors believe that the whole Software Engineering is in a pre scientific, non-engineering era, that it cannot be called yet engineering, but an well-educated craft [8]. Of course, many people disagree with this assertion. But we had no doubt that in Concurrent Programming we were efficiently training our students as craftsmen, not as engineers.

But to further develop this craft into engineering we need a suitable theory that can guide practice, and it is an evolving field. The answer we found was to help our students to develop some basic research skills.

**CONCURRENT PROGRAMMING FINAL ASSIGNMENT**

The final assignment is not a Thesis in the sense that we asked for no original contribution to knowledge. But we ask for things that can be solved organizing the work as if it were a written Thesis. Each student has to develop a different work.

As background information, they have to read a paper [9], where the authors survey parallel programming models and languages using some criteria to assess their suitability for realistic portable parallel programming. This paper adds a theoretical value to the background practice that students developed in the Labs and organizes the material they got at the lectures. We asked students to write a nutshell summary of the paper, with one sentence condensing the main ideas of each section, and to postpone reading the detail until it is needed. This recording activity is one of the skills we discovered we must help our students to develop, they have a natural inclination to record large amounts of details missing the big picture.

We use a huge Internet published book [10]. The size of the book discourages any attempt to read it in detail, so it is well suited as a summarizing exercise (as a matter of fact, something like the asked summary is included as a chapter of the book, but students were so structured in their assignment that they failed to find it). The book discusses the work done at the Caltech Concurrent Computation Program, Pasadena, California and is a hands-on complement of the previous paper.

After skimming the text on Parallel Computer solutions to some problems, students are asked to find a problem where a concurrent approach is worth applying. They also have to state the characteristics of the solution they want to develop by using the concepts and languages reviewed in the overview papers. They have to solve it using at least two approaches and to contrast them. They also have to find some axis of comparisons and to develop figures of merit.

We use the Organization of a Thesis as a skeleton for the final assignment asked to students. The final work has to include some mandatory sections:

I. **Introduction**: summarizing briefly the question the student is going to answer, and the reasons why it is a worthwhile question.

II. **Background information**: condensing the relevant points of the papers and lectures, and some results of a bibliographic review.

III. **State of the art**: reviewing whatever has been done that is relevant to the work.

IV. **Problem Statement**: providing a concise statement of the question the work tackles, the way it was worked out and the criteria for comparing this approach with others.

V. **Solution**: detailing what the student did and how.
VI. Conclusions: highlighting the inferences made because of the work. They have to be related to the statements of section IV.

HOW THE ASSIGNMENT WAS DEVELOPED

We devoted the final month of the class period to tackle with the students some relevant aspects of the work. Three things showed to be central in having the students understand how to accomplish the work.

One of the first things they had to learn is that the order of presentation in the Thesis paper is not the order they used to work it out. This was not obvious for students and we spent some time explaining with examples the stepwise approach. We also used some Internet pages [11] to point to some support material of the style of "... been there before, done that to success...". Knowing that it is natural not to write first the Introduction and that the problem statement is an iterative process lowered the anxiety a lot and allowed students to put hands on work.

They were asked to search the Internet and to use the Library’s resources such as scientific subscriptions to review if something has been done in the topic they chose to work with. Students had also to search for some free available implementation of the chosen language or paradigm able to be run in one of the computing systems they have access to. We had to explain that search results have to be evaluated in a systematic way [12] and that trusted search results are not of equal relevance. And also that students have to recognize it without reading all the material in detail. We asked for "three rings" of bibliography [13]. As bibliography and common sense suggest, we asked students to arrange their reading material in concentric interest circles. As an example, they sorted papers in three circles. An outer circle composed by papers somewhat related to their central point of interest. They could achieve an appropriate level of familiarity with the work in this circle by skimming papers or reading the abstracts. A middle circle where papers had to be read at least once and an inner circle with paper students had to work out in detail. As a result of this reading and sorting process, the central point of their work began to appear in the horizon. If interest was shifted papers moved among circles.

Once having the language or paradigm they will use and the problem they want to solve identified, they had to solve it. Of course, this is the part where students considered they were doing the real work, the kind of work they know best. We had to change our role from motivating or tracing to moderating. We asked students to identify blind alleys and dead ends as early as possible. It was difficult because students always thought that with one more week of work the blind alley would become a highway. We also had to convince them to stop throwing new features into the programming work and to begin with the writing. It proved to be a difficult point.

When we succeeded in stopping the programming work, we asked them to develop some form of metrics appropriate to the work they had done. Of course, this requirement called for a new bibliographic search and perhaps more programming. But they have to draw their own conclusions from their work.

Normally the class period ends with students in the reading and sorting phase. We asked them for a time schedule and they have to commit themselves to it. Students can choose a more traditional examination based way of approving the subject, but to date only a few non-majors made use of it. If some student fails to accomplish the self-imposed schedule, he/she is dropped onto the examination-based track. It has not happened to date.

OBSERVED RESULTS

We used this scheme for two terms, with a mix of Distributed Systems majors, who will take some follow on courses and Electronic majors, for whom it can be an end course. In the first term, from 12 students, the 7 majors and 2 non-majors chose the Thesis track. In the second term we had only 6 students, all majoring in Distributed Systems, and all chose the Thesis track. We only had a female student. She was one of the non-majors from the first course who chose the traditional grading option.

At the time of writing this paper, the 15 students from both terms finished their work. All of them did in on schedule. The little number may seem of no statistical significance, but Thesis is a highly individual work, and guiding them was a very personalized task. The impact of the different activities in the students is highly conditioned by their learning style.

All the works showed a coherent view of the chosen subject, that is more that we could say when we grade written or oral examinations. All of them were able to classify their approaches using internal problem specific or language paradigm criteria, and to explain these criteria. All of them found exciting material on the Web and some of them engaged in some sort of interaction with the community with similar interest, by sending their solutions.

We asked them to make some Web pages with a summary of their work and the relevant code. Three of them did it and their work will soon be on-line. The three had previous exposure to our learning style, writing and teaming works.

All of them passed the viva voce without problem. They also scheduled presentations with assistance of their fellow students. Their classmates and students of previous courses reacted with enthusiasm. Some of them manifested themselves inclined to repeat the experience, though they regarded it as highly technical and time consuming.

The three works with Web pages were submitted to conferences. One is related to the Ada view of concurrence and border detection from pictures, as opposed to traditional Kernel processing. Other is related to PARLOG and
PARLOG style coding compared with UNIX-C and the last is related to the Traveling Salesman Problem and OpenMP. It is important to remark that none of the student had previous exposure to image processing, functional languages or dynamic programming. In the border detection work and in the Traveling Salesman Work they used standard test cases and metrics to test their work. Unfortunately, it is difficult to have them to write the whole work in English to allow them a greater contact with the international community. 

It was difficult to convince students they do not have to include the dead ends they ran in their writings. We had to talk with them a lot to convince how to include the dead ends as conclusions and from a different non-frustrating perspective. They wanted to write a chronicle, not a Thesis. Their previous experience seems to prevent them from extracting the positive aspects of the painful work.

CONCLUDING REMARKS

Goal directed searches, though a time consuming task, is less frustrating than a broad search of the kind students are used to when they are asked for a research work and are not given enough concrete details. But the first time they do so, teachers must insist they have to use a method and they have to classify and evaluate their result somehow. It is better to begin this activity during the class period, letting students have enough freedom but preventing them from procrastinating.

The selection of a theoretical descriptive paper and a practical one proved to be the right one. Both of them enabled the students to not lose track of the relevant topics for the course such as Concurrent Programming and its Applications. The students who are beginning their Thesis are searching the bibliography for such kind of papers in order to choose a research project. If they do not find a suitable paper, they are convinced they have to work in a classification, taxonomy or contrasting project.

Students developed some contact with the international community. First by searching and visiting other Universities Web pages and understanding that things we asked them for are the same sort of things asked for everywhere. They also found communities dedicated to some kind of problems, as is the case with the Traveling Salesman Problem. They developed a solution and sent it for one of the contests the community holds on a regular basis.

Students learned the importance of standardizing different aspects of a problem in order to compare solutions. During the courses, the use of standard test sets is encouraged, but seen as an extra requirement of professors. Facing the need to compare two approaches, emphasizing contrasting differences, they actually see the need of standard sets. This is a major step in building an engineering oriented thought.

Each student found a methodology to deal with complex and unstructured tasks. They learned how to manage higher volumes of information than they were used to. They also found out how to organize the material and they developed their own style of doing it. The e-mail tracking of the process was echoed to all the students engaged in the Thesis work. It worked as some sort of technical meeting to exchange ideas. Students began to appreciate the benefits of these meetings. Due to their interaction they began to learn how to formulate new and interesting problems and to question established solutions.

Finally, students have entered a stage where they think about how they learn and solve problems. This approach is in line with the transferable problem solving skills industries are always asking for, beyond the shortsighted view of asking for an engineer trained in some specific tool. By learning how to monitor and regulate their learning, they have taken a big step to engage in lifelong learning.

REFERENCES


0-7803-7961-6/03/$17.00 © 2003 IEEE

Session S3E

33rd ASEE/IEEE Frontiers in Education Conference
S3E-8

November 5-8, 2003, Boulder, CO