Column: Student Forum

The Transfer of Technology in Students' Curricula

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***Abstract*—This article describes how projects for technological transfer from university research laboratories to enterprises and organizations can offer a stimulating working environment for students to do their *practicum* as required in many Computer Science Engineering Curricula. A key advantage is that students can effectively work in creative software product development and experience R&D processes.**

Many computer science engineering curricula around the world include a *practicum* in which students dedicate some hours working in a software business to gain practical experience in professional jobs. That practicum is usually an option that students may choose instead of studying some alternative optional courses.

Usually, students view the practicum as a good opportunity to become familiar with the professional world and to understand the real work software engineers must perform. In addition, students hope to do their practicum in software enterprises for which they are looking forward to work, and once there, they endeavor to demonstrate their skills in hope of receiving future jobs offers.

However, in many cases, software businesses look at these students as unexperienced low paid programmers, and therefore, only simple tasks are assigned to them such as programming small software modules under strict supervision and control. As a consequence, although the students are rewarded by feeling that they are working as professionals, they are often not provided with opportunities to experience performing sophisticated tasks such as requirements analysis, data and process modeling, etc. Even less common is the possibility of taking an active role in creative activities such as applying results from R&D to enable competitive advantages in a software product under development.

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What we propose is to provide students with a real workplace environment inside research laboratories, where they can develop their creativity and perform challenging work in projects where it is necessary to encapsulate R&D results in software products or to integrate different technologies in innovative ways. We believe that through this kind of early professional practice they will greatly enhance their professional background and confidence. A key aspect in this process is to allow students to assume responsibilities (under teacher/researcher supervision) that otherwise would be impossible to assume in software businesses.

In our experience in both of our countries, i.e., Chile and Spain, we have realized that inviting students to participate in technology transfer projects, called *innovation projects*, in which a research laboratory plays the role of a software business, has some advantages over the typical practicum in an actual software business. We will enumerate those advantages in the next section. We will also describe two successful experiences: one from each country and we then discuss some difficulties found in the process. Finally, we will present concluding remarks.

ADVANTAGES OF PROFESSIONAL PRACTICES INTO INNOVATION PROJECTS

Innovation projects based on R&D are normally developed by university research laboratories in order to provide solutions to problems arising in enterprises and organizations, which cannot be solved by the standard technology found in the market. Enterprises and organizations ask specialized research teams to solve problems that, at least, require an innovative use of existing advanced technology and the application of agile R&D methodologies to find solutions in practical times.

Therefore, the researchers leading those projects need to have a thorough understanding of the client's problems and the reasons why the current state of the art technology is not able to solve them. The research team will not only need staff to carry out the standard activities of the research process itself but also a number of software engineering activities such as analysis, design, prototyping, development, deployment, proof, and the final evaluation of the produced solutions.

In general, the advantages for the students doing their professional practices in innovation projects, rather than working in the standard software business, are the following.

1. Usually, when students carry out a practicum in an enterprise, they are asked to implement very specific software modules that are simple and perfectly predefined (a list with specific columns and filters, for example). They do not participate in the global analysis and design task. In contrast, normally, innovation projects need the rapid development of pilots or demos that are advanced in terms of technology but that are not usually huge applications that are impossible to know in their full extension. Therefore, students can have the opportunity of working in the whole life cycle of the pilot, from analysis and design to implementation, proofs, validation by future users, refinements, etc. In other words, in innovation projects, the students need to fully comprehend the problem to be solved and will, therefore, have a complete vision of the new service to be provided and not simply the partial vision required when developing a small fraction of a larger application.
2. Innovation projects are developed within the university; consequently, the leaders of such projects are also professors, and thus, they are aware of the students' scope of knowledge as well as what will present new challenges to them. This allows these professors to organize complementary teaching focused to cover aspects that are out of the standard curricula of the students but that are needed for the project. In addition, the leaders of these projects perfectly understand the needs and time constrains of the students, and therefore, they can adapt the project activities to the schedule of their courses. On the contrary, during their practicum in the software business, students must accommodate themselves to the schedule of workers outside the university scope.
3. In innovation projects, usually, advanced technology is integrated into an innovative way to compose the envisaged solution. This

provides the students the opportunity of working with advanced tools and methodologies which, in turn, give them the possibility of developing creative thinking.

4. In some cases, some additional research is needed that provides the students the opportunity of understanding how research is performed in computer science and, at the same time, enables them to learn how to search for information to know the state of the art and how to explore new approaches to solve a given problem. Through these activities, the students achieve greater confidence in thinking, researching, and learning for themselves. It is important to note that software systems are increasingly becoming more complex and that technology and methods are constantly changing; therefore, it is imperative that students understand, as soon as possible, the value of continuing their learning throughout their professional lives.

EXPERIENCE AT THE CITIAPS

The (http://citiaps.usach.cl) Innovation Center in Information Technologies for Social Applications (CITIAPS), is an R&D Center at the Universidad de Santiago de Chile (USACH). The projects developed at the CITIAPS are mainly oriented to produce software products that contain results from research where most of them are instances of technology push, namely they are software products that are not found in the market or the existing products are not sufficiently pertinent for the Chilean or even the Latin American context.

A key advantage for the students is that the CITIAPS is located at the Informatics Engineering Department (DIINF), that is, the same place where they pursue their undergraduate and graduate studies. This is a win-win situation as senior researchers at CITIAPS are also DIINF faculty members, and the students can participate in the R&D carried out at the CITIAPS through well-defined roles for professional practice: research engineer (e.g., data science, complex algorithms) and software engineer (front-end and back-end). There are additional opportunities for participation as part of their thesis work and short-term positions such as research assistant or team member in software project courses offered by CITIAPS to DIINF students. Postdoctoral researchers and Senior Research Engineers at CITIAPS are always involved in teaching undergraduate and graduate courses at DIINF, which contribute to strengthen relationships with students, as well as maintain a flow of students through the CITIAPS projects every year.

The R&D projects developed by the CITIAPS are usually supported by the Chilean research funding agencies, which also include additional funding from and partnership with enterprises and public organizations. To give an overall view of the type of projects that comprise the main focus of CITIAPS, we present a project related to emergency management for natural disasters. This is a project aimed to create a nationally distributed software infrastructure (enabling technology) capable of supporting eco-systems of resilient and high-ability software applications. This also involves developing a set of software products devised to support affected people, support civil organizations work (ONGs), and support decision makers from government institutions with responsibilities for civil protection during large scale disasters with impact in a large territory.

This on-going 4-year project has become an ideal environment for DIINF students to do their early professional practicum as the topic itself is highly stimulating (earthquakes are a relevant problem in Chile), and the research and engineering areas involved are diverse and challenging (scalable distributed computing, big-data, user experience, geo-apps, agile software development for technology push, etc.).

EXPERIENCE AT THE LBD

The research group LBD (DataBase Laboratory) (http://lbd.udc.es) is comprised of 12 Ph.D. professors in computer science that work as faculty members at the Universidade da Coruña (UDC), Spain. The LBD has a long experience in the development of innovation projects for different kind of enterprises, some of them related with software production, but others, such as those involved in the project we describe below, are not involved in ICT areas.

In a recent project called GIRO, we worked for a consortium of six enterprises from different business areas (from home care to waste collection) whose only common characteristic is that they have employees that perform their work by traveling around from customer to customer.

The problem for these enterprises was that, although there exist in the market some software products for the management of mobile workers,[1-3] (known as Mobile Workforce Management products), they were not suitable for their specific needs. Part of the problem was that these enterprises had constraints related with the management of their business that those software products did not properly support. On the other hand, they needed automatic planners for routes and activities that were far more complex than the usual planners available from the commercial software products. The project developed for each enterprise a software application that integrated an ad-hoc planner that resulted from research based on the application of Operations Research and Artificial Intelligence techniques. On top of these solutions, a set of customized software applications were developed for each enterprise, which also included additional tools to assist the management supported by automated data analysis and visualization using Geographic Information Systems technology.

A very innovative service we provided to each enterprise was the segmentation of the trajectory followed by each worker.[4] Each trajectory was split into fragments that were then semantically tagged with labels describing the kind of activity the worker was performing at that moment, for instance, driving in slow traffic, searching for a parking space, walking to the customer address, working into the customer installation, etc. To identify the activities that a worker was doing at each moment we used the sensors of his/her mobile phone (GPS and accelerometer) and the respective cartography and schedule for the worker. All of these elements provided an attractive technical challenge for the students involved in the project.

At present, the enterprises use the software applications developed in the project, and a spin-off software enterprise created by the LBD provides maintenance services and extensions to these software applications. Many of the former students that worked in the project became part of the spin-off enterprise.

PROBLEMS AND OTHER CONSIDERATIONS

In our experience, there are evident benefits to students by doing their practicum in innovation projects based on the application of R&D, that is, projects oriented to the transfer of technology and research results from the universities to the enterprises and organizations. It is also undeniable that without the help of many students working in the development of such projects, it would be impossible for research laboratories within the academic world to create the solutions that enterprises demand. However, some questions arise because the process of integrating students in the development of those innovative solutions is not always easy.

First consideration is the specific role the research laboratory must play in the development of those solutions. In some cases, the enterprises contracting the research laboratory are software business, which are merely interested in the research results because they are capable of developing the software products themselves by following the directions provided by the research team. Thus, regarding the students involved, those projects in which the enterprise or organization contracting the research laboratory needs a perfectly proven functional solution, evaluated in the real context and improved consequently, are far more interesting. That is, these enterprises request a professional, robust and reliable software product solution already proved and ready to use. For the research laboratory, however, a relevant issue here is not to forget that they must not get involved in projects without a clear R&D component, or at least a strong innovative nature, so that students could indeed participate in projects posing relevant technical challenges.

In those projects aimed to the development of final reliable solutions, many students need to be involved, but as they are inexperienced professionals, a very close supervision of their work is required. However, such supervision is only possible if the research team have senior engineers and researchers with enough experience

and time to perform not only the supervision of the student work but other tasks as well. For example, activities related with the research work needed by the project itself, talks oriented to increase the technological knowledge of the students, and activities oriented to stimulate and encourage the students to present their own ideas and propose new solutions. Unfortunately, research laboratories do not always have such senior staff with enough time for developing those activities, and therefore, in some cases, research laboratories can only commit to develop projects in which the software product reaches only the prototype level.

CONCLUSION

The funding obtained by research laboratories dedicated to innovation projects based on R&D has a twofold social interest. It helps to support research activities that, in this way, have additional financial resources besides public grants. Furthermore, the main part of the funding can be employed for supporting students in the development of the projects. This increases student opportunities for performing early professional work in a more stimulating environment than the normal practicum in software businesses. At the same time, those projects introduce students to the understanding of how the relationship between the academic and research world can interact with the business world to provide solutions beyond the state of the art. This understanding will certainly become useful for them later on in their professional careers as they are better prepared to introduce R&D based innovation in their respective enterprises or entrepreneurships.

For this process to work properly, it is essential to have senior researchers and engineers at the university research laboratory with enough time not only to perform the R&D process itself but to properly assist the students involved in the project as well. It is also essential to encourage the students' use of professional methods and practices, as well as introduce them to the application of advanced software technologies and techniques, and foster in them a positive attitude towards creative thinking.

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