Generation of Critical Mass in Education

An Initiative to Engagement

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***Abstract*—The lack of professionals is considered a major risk to the Industrial Pole installed in Manaus, Brazil. Specially, STEM education is intricately difficult and if the student is not well involved, supported and motivated, the chances of success are very low, which can be verified by the 25% to 30% dropout rate per semester in our institution. Given this scenario, a qualification program denominated "multiple vortexes of know-how" was conceived to address three aspects: i) reduce student dropout; ii) enlarge the reachable community; iii) offer different levels of knowledge. Vortex is in essence an action, working interconnected and coordinated to other vortexes. Four different actions were prepared: classroom disciplines; a talent development program; holding short-term events, and enrolling in intensive training. This present work describes the vortex that enrolled the major number of students: the classroom disciplines. A catalog of optional undergraduate and graduate disciplines was offered to the students. The best students received a prize based on their performance. In summary, we had around 650 students qualified with 84 scholarship prizes granted. The paper will present as a contribution to the program, the catalog of disciplines and recommendations on how to proceed with the activities.**

Keywords— STEM Education; Computer Science Education.

I. INTRODUCTION

Brazil has a strong demand for highly qualified professionals, especially in remote areas. Manaus, the capital of the state of Amazonas, is distant and isolated from the major business centers and experiences a critical situation. The lack of professionals is considered a major risk to the Industrial Pole installed in Manaus. Preparing students to the market is a challenge as there are few undergraduate courses related to technology and the typical dropout rate is very high. Science, Technology, Engineering and Mathematics (STEM) education is intricately difficult and if the student is not well involved, supported and motivated, the chances of success are very low, which can be verified by the 25% to 30% dropout rate per semester in our institution.

Brazilian rulers already have an agenda for the country concerning higher education. However, government strategies tend to take time to show results and some industries in Manaus have urgent needs. Therefore, we have proposed an approach that can be seen as complementary to long term government strategies. It is, in essence, a joining of industry and academy to create critical mass on a specific area. The goal is to fulfill the demand of hiring a few hundreds of professionals in a three-year timeframe, with a level of investment that does not compromise the overall R&D (Research & Development) investment already planned for the same period. This approach is a program called PROMOBILE (Large Scale Qualification PROgram on MOBILE Technologies) and it has been applied at the Institute of Computing at the Federal University of Amazonas.

The proposed program fundamentals lay down on an approach we denominated "multiple vortexes of know-how" to simultaneously address three aspects: i) involve students on learning activities to reduce student dropout; ii) reach the largest number of students and people from the community as possible; iii) offer different levels of knowledge, related to a specific topic, but also working on building a competitive professional profile.

Very few similar initiatives of creating critical mass in education were found. In fact, only the Moroccan PAAFE program [1] is similar to the scenario previously described. However, PAAFE addresses a much higher scale (hundreds of thousands of students) and with a much more distinctive investment (almost half a billion dollars) than our program. Moreover, the principles behind the proposed methodology are also presented in other related experiences. In [2], the author mentions five aspects that might be addressed by a higher education institution to increase the success rate of students, all of which are considered here. A special attention was given to the aspect of strong involvement of the students in a variety of learning activities, as it is also pointed out in [3]. Those works provided important information as basis on how to create learning activities.

The present approach extends those methodologies by giving to the activities a context of unit and common goal. The Student Involvement Theory advocated in [3] is applied to a specific domain, without losing its general principles. Moreover, the proposal of the activities is to work on a broadset of student abilities (both hard and soft skills). In other words, we want to build not only know-how, but also a profile.

This present paper describes the whole concept, but in more details the vortex that enrolled the most significant number of students: the classroom disciplines. A catalog of optional

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undergraduate and graduate disciplines was offered to the students. The enrolled students had the opportunity to participate on a sort of learning activities, including classes and laboratories with industry experts. The best students received a prize based on their performance. To be eligible to one of the scholarship prizes, the student had to succeed as top 25% in the discipline and could not fail in any other discipline. The number of students enrolled in the disciplines exceeded all the expectations. In the first year of the Program, we offered eight disciplines, which worked on all technical aspects of the Android platform and touched another technology (under the request of the company sponsor): Tizen™. In summary, we had around 650 students qualified with 84 scholarship prizes granted. The paper will present as a contribution to the program, the catalog of disciplines and recommendations on how to proceed with the activities.

The remainder of this paper is organized as follows: Section II presents a short context of the issue and the actors involved with the proposed solution; Section III details the program PROMOBILE, along with the goals and premises used to propose the methodology, with emphasis on the disciplines; Section IV presents the partial results and the lessons learned so far, and, finally, in Section V, we conclude the paper with a few important remarks.

II. CONTEXT

The three spheres of Brazilian government (Federal, State and Municipal) defined a series of tax reduction policies in Manaus to promote the establishment of R&D activities by the companies with facilities in its free trading zone. The driven law, nicknamed as Informatics Law for Manaus free trading zone [4], has the explicit intention to deepen the product value chain in the region with local added-value.

In an urge to fulfill the increasing demand for highly qualified professionals, government and private companies created new or improved existing local courses of higher education on a diversity of STEM related areas. Despite the improvement of the ranking of universities and colleges nearby, Manaus is located in the Northern region of Brazil, where the education is in the lowest position countrywide. As a consequence, the efforts to increase the number of tech courses contrasts with the usual poor background of undergraduate candidates, leading to an overall dropout rate as high as 80%. Furthermore, the remaining 20% alumni sometimes struggle with the intrinsic difficulty of computer programming [5] besides the lack of most basic skills such as Portuguese (our native language) writing or oral presentation. For the most qualified ones, sometimes the lack of English skills prevent them to access the best positions.

One may suggest the trivial solution to relocate qualified people from other places to Manaus. After all, we live in a global market, global companies have a long term experience with moving outsiders from here to there, and Amazon rain forest has its appeal, one may argue. However, it is not easy to hire highly qualified personnel for positions in Manaus. The city is isolated from the rest of the country, surrounded by the jungle, with road connection to very few cities, and the flight ticket is more expensive than average. As many Brazilian big cities, Manaus has severe infrastructure problems, including: poor public transportation, high living cost, all-year hot and humid weather, typical of the Amazon rain forest. So we get to the conclusion: relying on relocating professionals to Manaus is unrealistic.

The solution then is to invest in local human resources. And the best way is to invest in education. So this proposal is an approach that tries to join industry and academia through a coordinate initiative that is better explained in the next section.

III. PROMOBILE

An earlier paper describes the first edition of the program, accomplished in 2013 at the Institute of Computing at the Federal University of Amazonas [6]. The results were quite positive: over 700 students were involved and motivated with these new possibilities.

The theoretical framework for this study is based on Tinto's model of student departure which emphasizes the importance of academic and social integration on student persistence [2], and Astin's theory of student involvement and its role in student development (e.g., highly involved students study a lot, spend a lot of time on campus, participate actively in student organizations, and interact frequently with faculty members and other students) [3].

Astin had also created five basic assumptions about involvement [3]:

1. Involvement requires an investment of psychosocial and physical energy;
2. Involvement is continuous and the amount of energy invested varies from student to student;
3. Aspects of involvement may be qualitative and quantitative;
4. What a student gains from being involved (or their development) is directly proportional to the extent to which were involved (in both aspects of quality and quantity);
5. Academic performance is correlated with the student involvement.

Considering these five assumptions very important to a high quality education, the proposed program fundamentals lay down on an approach we denominated "multiple vortexes of know-how" to simultaneously address three aspects:

1. Involve students on learning activities to reduce the student dropout;
2. Reach the largest number of students as possible;
3. Offer different levels of knowledge, related to a specific topic, but also working on building a professional profile.

Each vortex is in essence an activity, working on aspects of qualification (quantity and/or quality). The output of a given activity is directed to the next, benefiting from the motivation of increasing the desire for further knowledge, i.e., the following action offers a new opportunity for the enrolled

student. Once finishing a cycle the student will move to a new activity and then to another as shown in Fig.1.

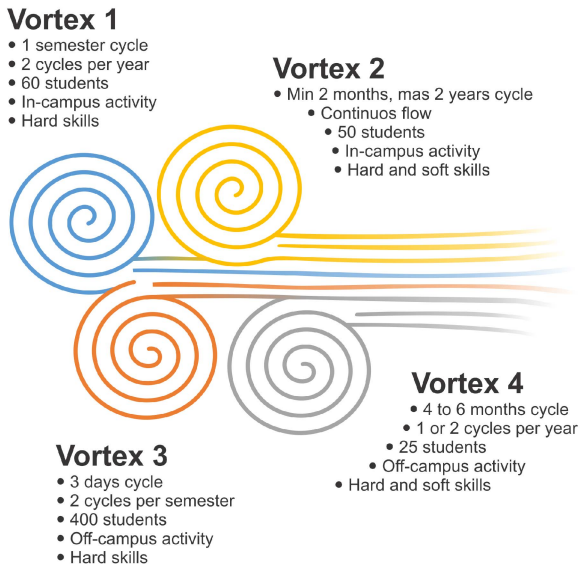

Fig. 1. Four activities (defined as vortexes) cooperate to increase the qualified personnel in both quantity and quality in a specific area.

Activities were specified in terms of its ability to promote growth in competence (quality) and/or capacity (quantity), without that critical mass is not achievable.

In this work, a Vortex is an involvement activity defined in one or more cycles, with a self-contained subject, and connected to another Vortex in such a way to contribute either in depth of knowledge or in number of persons to the whole program.

In this approach, four vortexes were defined:

- Vortex 1 – **Undergraduate and graduate disciplines**: a catalog of optional disciplines was offered to the students. The enrolled students had the opportunity to participate on a sort of learning activities, including classes and laboratories with industry experts. The best students received a prize based on their performance. In order to preserve the other aspect of the curriculum, a student that failed in any discipline would not be eligible to the prize, even if he passed in first place in a vortex discipline;
- Vortex 2 – **New talents development program**: we defined a set of scholarships, with clear granting and maintenance requirements. The candidates were enrolled in cycles of off-class project activities with different degrees of challenges in different aspects, from hard to soft skills. Project management, software development process (agile methodology), English, writing and speech skills were part of the program. Highly productive students received leadership coaching. They also coordinated a small group of colleagues, and received a differentiated scholarship;
- Vortex 3 – A **short term event** (three days) took place at each six months to bring together students from Vortexes 1 and 2, as well as attract students from other institutions and professionals. The event had three tracks: motivational, technical and a student contest. The goal of this activity was mainly to attract new participants to the program;
- Vortex 4 – A **medium term advanced qualification training**, prepared either to senior students or to professionals that are already in the market. The threshold of this training was set very high in terms of qualification level. It is highly recommended to be accomplished by a top professional of the field.

The goal of this program is to prepare around four hundreds of new professionals in a period of three years. The four vortexes were implemented in a roll, starting from Vortex 1 – undergraduate and graduate disciplines, which is explained in the next subsection.

In Vortex 2 – new talents development program, we tailored a well-known agile software development process (SCRUM) to fit to our context and to uniformly induce the learning actions. This vortex has been described in an earlier paper [7] and the other vortexes should come in further publication.

A. Classroom Disciplines

This was basically the main activity on Vortex 1. It had a one semester cycle, with two cycles a year. The goal was to achieve about 60 students per semester in in-campus activities to develop technical skills. The disciplines were offered in both undergraduate and graduate levels, with content focused on some aspect of software development for portable mobile and distributed systems that use Android and Tizen™ platform. Some of the topics were: (i) programming and algorithms for portable and mobile platforms; (ii) safety aspects for portable and mobile platforms; (iii) usability aspects for portable and mobile platforms; (iv) advanced topics in software development artifacts for portable and mobile platforms; (v) advanced topics in application design for portable and mobile platforms and their interoperation with intelligent mobile agents; and (vi) advanced topics in distributed and collaborative systems.

In this activity, we had the opportunity to involve other professors from the Institute, who had different expertise with interesting research in different areas. Each professor was free to invite industry experts to enrich the class with their experience. The classes could be either in rooms or laboratories and the dynamic was more on professor's choice.

In this activity, the company sponsor participated in the following items:

- Project status monitoring meetings in order to ensure that all activities were being carried out with quality and serving the set schedule;
- Monitoring financial management as well as intervention in the release of expenditures;

- Process of releasing mobile devices for applications development.

Students were encouraged to enroll the classes as they had interesting and up-to-date syllabi. The best students with good performance on the discipline and in the course would receive a scholarship prize. At the end of each semester the applications developed were presented in a fair. Its main objectives were: (1) disclose to the community the results obtained in the disciplines sponsored by PROMOBILE; (2) strengthen students' ability to present and defend a design/prototype and; (3) expose the project brand.

At the end, we would like the student to be really involved with the discipline and the course based on Astin's five assumptions:

1. Disciplines required substantial investment of psychosocial and physical energy. They lasted a whole semester, with two weekly meetings. Assignments required most of the times working in groups;
2. Involvement was continuous. Each professor was free to use his own evaluation process. One of the requirements was that students should spend the whole semester dedicated to the discipline, but the amount of energy invested varied from student to student. Even their levels (under or graduate) were considered;
3. Students were involved both in qualitative and quantitative ways. In all disciplines, a product should be the outcome. This would involve many qualitative abilities like comprehension, analysis, problem solving, etc. Quantitative involvement would be the extra hours spent in the project;
4. Well involved students were awarded with recognition and a prize. The fairs brought a lot of feedback and prize was given only with confirmed good performance in the entire course;
5. Academic performance correlation with the student involvement is not confirmed yet, but we have awarded only the best students based on grades and on professor's testimonials.

Next section presents the results obtained so far. They are based on the disciplines offered, students' involvement and an opinion survey to evaluate this PROMOBILE vortex.

IV. Results

As mentioned before, in this paper we focus our analysis on the classroom disciplines vortex of the PROMOBILE program. In this section, we show the main results obtained in this vortex as well as the analysis of a survey conducted among the involved students in order to evaluate the proposed actions.

A. Classroom Disciplines

Table 1 shows the catalog of undergraduate and graduate disciplines that were offered to the students as well as the number of both enrolled and succeeded students.

In total, we had 21 different classes from 12 different disciplines during the three years of the program. Approximately, 650 students were enrolled by the disciplines, although the number of distinct students may be lower since a student could participate in more than one discipline.

As we can see, the main common theme among all the disciplines were "mobile devices", since it was one of the goals of the PROMOBILE program. Some disciplines focused on teaching the required general skills for mobile devices programming such as the disciplines: "*Programming Techniques*", "*Programming Laboratory*", and "*Programming Mobile Devices with HTML5*". Other disciplines were focused on more specific subtopics:

- "*Distributed Systems*" focused on teaching the development of client/server-based applications;
- "*Special Topics in Software Engineering*" and "*Mobile Applications Engineering*" focused on the modeling and analysis of mobile applications;
- "*Collaborative Mobile Systems*", "*Mobile Social Computing*" and "*Content Delivery Networks*" focused on applications in which users have an active role that allows the functioning and usefulness of a web-based service;
- "*User Experience*" focused on the interface of the applications, allowing the development of more user-friendly and well-designed interfaces;
- "*Security in Mobile Devices*" focused on the security aspect of applications and protocols; and
- "*Game Development for Mobile Devices*" focused on the development of games that are specific to mobile devices.

In order to further motivate the students enrolled in the classroom disciplines, we conducted two main events at the end of each semester: the (1) Mobile Applications Fair and the (2) Best Students Award.

1) Mobile Applications Fair

Most disciplines offered by the program generated several mobile applications that were developed by the students during the semester. In order to stimulate the students and allow them to show the results of their work, we organized several Mobile Application Fairs, in which selected students were able to demonstrate the developed applications to the general public. In these fairs, each student had a poster showing the main goal, features and screenshots of the developed application. A live demonstration of the applications was also conducted to the interested visitors.

Three main fairs were conducted during the duration of the program with each fair having about 15 different posters and applications. Since the event was advertised in several different media (e.g., Facebook, mailing lists, local sites) we had the presence of several interested groups such as local students (from our course and from other courses), students from other institutions and also professionals from the industry and

TABLE I. *PROGRAM-SPONSORED DISCIPLINES AND NUMBER OF BOTH ENROLLED AND SUCCEEDED STUDENTS PER SEMESTER*

	Discipline	2013.1	2013.2	2014.1	2014.2	2015.1	2015.2
1	*Distributed Systems*	7 / 7					
2	*Special Topics in Software Engineering*	25 / 24					
3	*Programming Techniques*	21 / 15	49 / 26	82 / 50	48 / 23	33 / 21	50 / 33
4	*Collaborative Mobile Systems*		39 / 22		26 / 26		24 / 13
5	*Programing Laboratory*		20 / 13		14 / 6		
6	*Content Delivery Networks*		7 / 5				
7	*Programming Mobile Devices with HTML5*		39 / 30				
8	*User Experience*			19 / 18			
9	Security in Mobile Devices			8 / 8			
10	*Game Development for Mobile Devices*			38 / 17		36 / 20	
11	*Mobile Applications Engineering*					52 / 27	
12	*Mobile Social Computing*						15 / 12
	***Total** (652 / 416)*	53 / 46	154 / 96	147 / 93	88 / 55	121 / 68	89 / 58

academia. We had an estimation of more the 300 visitors for each fair.

2) Best Students Award

For each of the 21 offered classes, PROMOBILE program had awarded scholarship prizes of R$ 1000 (~US$ 280) for the best students. Depending on the performance of the students, one to six prizes were awarded for each class to a total of 84 prizes awarded during the three years of the program.

In order to not jeopardize the other aspect of the curriculum, students that failed any other disciplines in the same semester (even those out of PROMOBILE scope) were not eligible to the prize. These rules were all explained to the students in the beginning of each semester.

B. *Survey Results*

At the end of the classroom disciplines, we conducted some surveys in order to better understand the impact of the program initiatives on the motivation of the students. These surveys were completely anonymous, not mandatory, and simple enough to be answered in less than five minutes. In total, we had 113 students that answered the survey.

In what follows, we show some of the main questions regarding the motivation of the students and we discuss some of the obtained answers.

1) Was your interest towards the discipline increased due to the fact that it was sponsored by the PROMOBILE program?

One of the impressions we had in the beginning of the PROMOBILE program is that students would be more interested in a discipline that was offered by an industry-based program, such as PROMOBILE, since most of them will be headed to the industry after graduation. As depicted in Fig. 2, we can see that our impression was in fact true, since 86% of the students that answered the survey agreed that they were more interested in the sponsored discipline, even though 28% of them were only barely more interested. This is an interesting point, since it shows that, regardless the other motivational aspects of this vortex (prizes and fairs), the sponsored aspect of the disciplines alone was able to increase the motivation of the students.

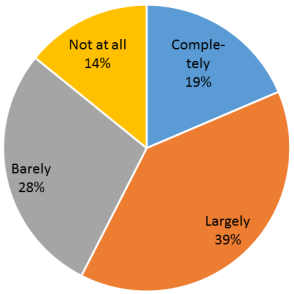

Fig. 2: Increased interest on a sponsored discipline.

2) Was your interest towards the discipline increased due to the best students' prizes?

With this question, we tried to isolate how the prize for the best students affected the interest of the students as a whole. Analyzing the answers depicted in Fig. 3, we can notice that 90% of the students agreed that the prize at the end of the discipline increased their interest even more.

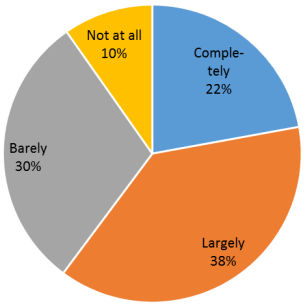

Fig. 3: Increased interest on a discipline with best students prizes.

3) Was your interest towards the discipline increased due to its up-to-date, industry-based topics?

Even with our initial impression that having up-to-date, industry-based topics in the sponsored disciplines would increase the interest of the students, we were still impressed by the answers, depicted in Fig. 4. Not only 100% of the students agreed that the disciplines topics were up-to-date but also 97% agreed that this fact increased their interest toward the disciplines.

Comparing these answers to the previous questions, we can see that the students were more motivated by the topics of the disciplines than by the other aspects.

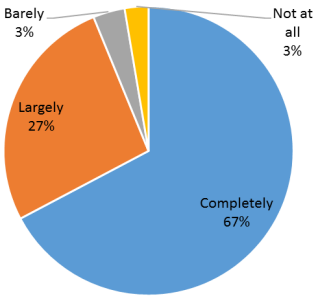

Fig. 4: Increased interest on a discipline with up-to-date topics.

4) Was your interest towards the non-sponsored disciplines increased due to the fact that you could not fail them in order to compete for the prize?

This question was proposed to better understand how much the prizes were able to affect the students. The answers, depicted in Fig. 5, showed us that even though it was an important aspect, 58% of the students were at most only barely more interested in the other disciplines in order to compete for the best students' prizes.

This is an interesting result, since it shows that the prizes have a limited motivational aspect and that some students are only willing to go this far in order to compete for the amount of prizes offered.

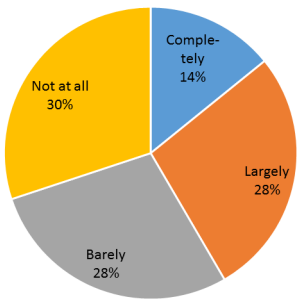

Fig. 5: Increased interest on other disciplines.

5) Do you approve the fact that a company sponsored a discipline?

6) Do you think it was made too much advertisement of the sponsor company?

One of our concerns in the beginning of PROMOBILE program was how the students would see the fact that a commercial company was sponsoring a discipline.

However, the survey results depicted in Fig. 6 and Fig. 7 clearly show that the majority of the students not only agree that it is fine for a company to sponsor some disciplines but they also agree that they did not felt that too much advertisement was being made.

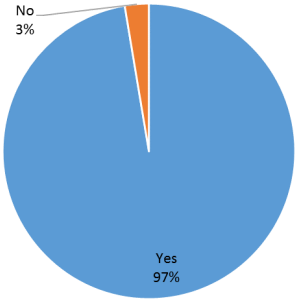

Fig. 6: Approve a sponsored discipline.

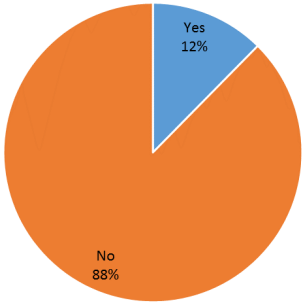

Fig. 7: Too much advertisement.

V. Conclusions and Lessons Learned

The Classroom Disciplines vortex of PROMOBILE was one of the most active part of the program and the one that affected the highest number of students. We have collected some lessons learned during the last three years of running this vortex. We divided them into positive (those we did and it proved to be important) and negative (we learnt by failure).

On the positive side, it is almost unanimous among the students the increase of their interest on the sponsored disciplines. However, the main reason for this was not the financial aspect (prizes), but mostly the fact that an industry-based company was supporting the disciplines and helping improve and update the studied topics.

Another key positive aspect of the program was the Mobile Applications Fair. It was very interesting to notice the initial resistance of the students in the beginning of the semester (when they were told they would need to present the developed application) and, then, their complete support to the fair during and after the event. Again, their main motivation was the possibility of showing their work to the industry representatives and, also, the feeling of developing and having to defend a "commercial" product. A good portion of the students really embraced the idea and went far more than expected in order to have a complete and innovative product.

On the negative side, we did notice some aspects that could be improved in future similar programs. For instance, we did expect the offered prizes to be one of the main motivations for the students. After all, nothing like this had been done before in our institute. But, as depicted in Fig. 4, when faced with the restriction that the student need not to fail other disciplines, most of them stopped caring about the prizes. When we asked the reason on our survey, some of them answered that (1) they were overloaded in disciplines, (2) some disciplines were just too hard, (3) the prize value were not enough, or (4) some of them simply did not believe they could win the prize. These four points lead us to reflection and should be worked out in future work.

The Mobile Applications Fair was also not perfect. Unfortunately, we did not have a room with enough space for a big event. Thus, we tried to limit the number of presenters and use a medium sized room, which resulted in some complains such as (1) too much noise (several people talking at the same time), (2) warm room due to an overloaded air conditioning, (3) lack of chairs for all presenters, and, in some cases, (4) slow Internet due to an overloaded router.

Another negative aspect was that, since we were trying to reduce the amount of advertisement in the disciplines, some students actually thought that we should have included more the sponsor company in our actions. For instance, they complained that we did not bring enough people from the industry to talk to them in lectures. Also, some of the students suggested that the prize for the best students should have included a visit to the sponsor company or, even, to become an intern in the company. These suggestions and the data presented in Fig. 5 and Fig. 6 really indicates that the students approved the presence of a company's name in the disciplines (to a certain extent) since, as mentioned by some students, it reduces the distance between the industry and the academia.

Turning our attention to the company side, we really believe that the sponsored disciplines were able to achieve their goals of educating and training high quality personnel that were better fitted to the company's interest in order to strengthen their competitive position in this emerging field of mobile devices. Students enrolled in our disciplines were not only able to develop mobile applications but also had the chance to explore and learn more specific subjects in the area such as design of interfaces, security, modeling, and social and collaborative services.

Finally, the positive response and the impact on the student performance motivated the professors to expand the action to other campi. The replication of the activity on a second university was even more encouraging, especially when considering their severe limitations in terms of undergraduate students.

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