# Using an IT Laboratory for Training IT Architects

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Abstract: Information Technology Architecture (ITA) has been known for its importance in the alignment of the business's needs and its technological strategies. As the companies have become more complex and the market more competitive, ITA has gained more significance and the demand for IT architects has strongly increased around the world. Nonetheless, the offer of qualified architects is not growing as fast. This is because a qualified IT architect is not easy to find as he or she has to possess many hard and soft skills. It is not a surprise then, that the time frame required for a professional to become an experienced IT architect is too long, the necessary experience is difficult to acquire and the skills are difficult to develop. This paper proposes a way to help students and professionals obtain these elements through a project based approach supported by different reality simulated enterprise cases. These cases compose what we call an IT Laboratory.

## 1 INTRODUCTION

IT Architecture is the discipline that focuses on designing and delivering valuable technology strategies to companies (Marks, 2016). It differs from Enteprise Architecture because IT Architecture not only comprises the design and planning of the IT solution that complies with the business's needs, but also includes the implementation of that solution. In recent years, IT Architecture has gained considerable importance due to its high impact in organizations. IT Architects are in high demand around the world but, as it often happens in IT related jobs, there are not enough qualified professionals for the role. With the goal of producing a profile which can deal with the market challenges, many organizations and institutions offer training programs for IT architects. Those programs vary from seminars or short courses to extensive and long ones. Programs such as The Open Group TOGAF Certification Program (Scherer and Wimmer, 2011), Certified IT Architect (CITA) (Clements, 2010), and IEEE Computer Society's Certified Software Development Professional Program(IEEE, 2005) are quite popular and aim to produce highly adaptable professionals, with deep industry comprehension, high business insight, and profound technology knowledge.

However educating architects is a difficult task, as the real world comes with a lot of different contexts, challenges, risks, and uncertainty that they will have to face. Thus, in order for students to gain the insight and expertise for a real IT architecture project, they need to obtain not only theorical knowledge but practical experience as well. One alternative is practising in a real enterprise project. However, this would be too risky for the enterprise, take too long, and will only let the students practice on some very specific problems.

With the purpose of offering a more complete training for professionals who want to become IT architects, we propose the use of an IT laboratory which consists of a set of simulation scenarios regarding fictional organizations. These scenarios resemble a complete organization with strategic and operational components and real technology implementation supporting it. Furthermore, the scenarios illustrate different industries in order to make students learn about different verticals. They also recreate the complexity and imperfection of a real company. Taking those scenarios as a base, the students can have an environment to practice, reinforce, and integrate all the concepts concerning analysis, design, and implementation of IT architectures.

An IT laboratory is used on several academic projects focusing on different phases of IT architecture projects. The focus in each phase is determined according to the course and program level, and the set of skills the students should acquire or improve. At the end of the projects, the achievement of those compe-



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tences can be evaluated. With the purpose of giving the students interesting projects to work on, the objective and scope of the projects should be carefully defined and the evaluation schemes adjusted and validated.

The paper is structured as follows. Section II describes what an IT architecture project is. Section III explains what a project based approach is. Section IV details the proposed definition of an IT laboratory used to train students and professionals. Section V shows a case study of the IT laboratory use and evaluation in an academic program. Finally, Section VI presents the conclusions regarding the benefits of the IT laboratory.

## 2 IT ARCHITECTURE PROJECTS

An IT Architecture Project is typically distributed in non-linear phases or cycles. Each cycle has an internal set of activities and its purpose is to obtain a product or deliverable once it is finished. Also, at the end of each cycle there a stakeholder's validation in order to get feedback and do the necessary adjustments.

We created a model with the common cycles in an IT architecture project process and its activities. This model, as shown in Figure 1, is based on different frameworks and methodologies such as (Team Software Process) TSP (Humphrey et al., 2010), (Rational Unified Process) RUP (Shuja and Krebs, 2007) and TOGAF's ADM (Harrison, 2011). The proposed process includes activities that go from planning to executing and deploying the solution, distributed through six major phases: (PP1) Planning, (PP2) Information Gathering, (PP3) Analysis, (PP4) Design, (PP5) Roadmap, and (PP6) Implementation. Each phase and its deliverables (such a document with the models or a code part) composes a portion of the final product to be delivered to the final users. This incremental approach assures quality and relialibility of the product through continuous refining and adjustment. Because of this, in a typical IT Architecture project it is not strange to find redesign steps in subsequent phases.

It is important to note that some frameworks and methodologies do not consider the final phase (PP6) Implementation as a part of an IT Architecture Process but more as a part of the Development Process. Nonetheless, we firmly believe that an IT Architecture is not complete until the final product is released. Moreover, the IT architect must be involved in all the phases even if the final step is performed by a development team. The reason for that is twofold: the architect's insight is truly important on the development tasks and a qualified architect must have profound knowledge of the development stages in order to get the expertise to execute ITA projects correctly.

In order to train architects that can adequately perform an ITA project, they should have many skills concerning technology knowledge and personal abilities. To define these set of skills we performed a literature review and enhanced them through surveys and interviews with instructors and IT experts, as recommended by Kalampokis (Kalampokis et al., 2012). In the review we took into account the different roles of an IT architect and the competences each role needs to have in order to sucesfully contribute to an ITA project according to TOGAF (The Open Group, 2011), IASA (International Association for Software Architects, 2016), TSP (Humphrey et al., 2010), and RUP (Shuja and Krebs, 2007). We also included the Accreditation Board for Engineering and Technology (Felder and Brent, 2003) which defines a series of abilities, called student outcomes, that represent what students from any discipline are expected to know and be able to do. Making a match between the consulted sources and the expert's validation, the list was completed and edited. The list is presented on table 1. Using this list as a baseline, we calculated skills required in every phase of an architectural project, as shown in Figure 2.

## 3 PROJECT BASED LEARNING

Project Based Learning (PBL) is a pedagogical approach which aims to confront the students with problems and challenges similar to those found in the real world. It is mainly based on giving the students the opportunity to not only memorize concepts but also put them in practice on different projects and activities. PBL integrates knowing and doing. Students acquire knowledge and learn elements of the core curriculum, but also apply what they know to solve authentic problems and produce results that matter (Markham, 2011). More information about PBL work scheme and advantages can be found on (McCormick, 2008) and (Wankel, 2005), respectively.

Additionally, there has been research on the use of IT in the PBL approach. The use of IT technologies can be extremely helpful when defining projects because they can simulate real environments where students can practice. This is the case of Hypercase, an interactive system's analysis and design simulation tool which is used on different courses and books. More about Hypercase can be consulted on (Kendall and Kendall, 2014).

In order to correctly apply the project based approach, students must be confronted with reality simula-

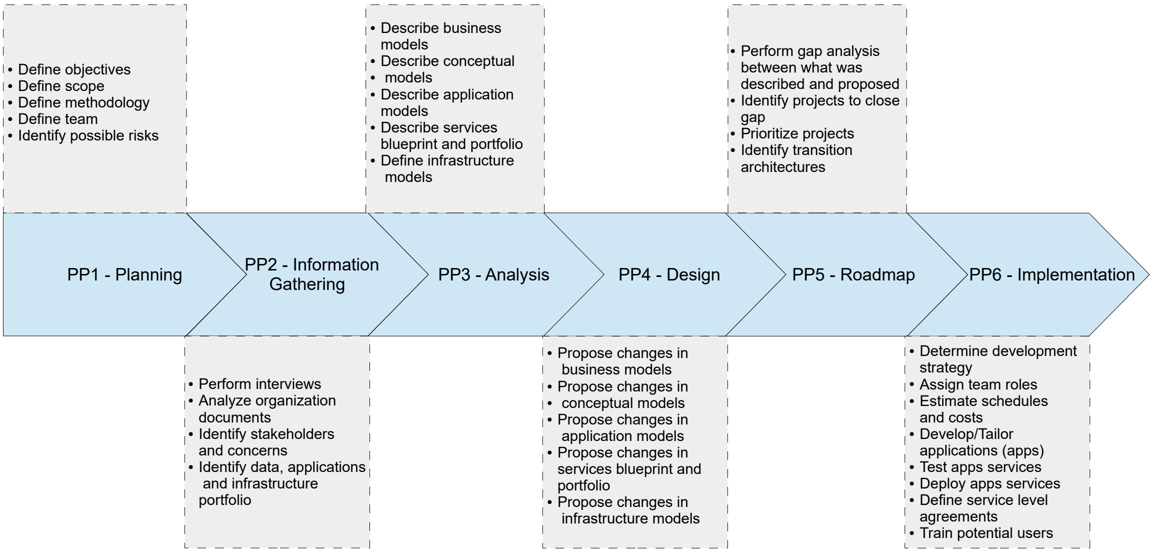


Figure 1: IT architecture project process.

| | PP1 | PP2 | PP3 | PP4 | PP5 | PP6 |
|---|---|---|---|---|---|---|
| SK1 | ■ | | ■ | | ■ | ■ |
| SK2 | | | | ■ | ■ | |
| SK3 | | | | ■ | ■ | ■ |
| SK4 | ■ | ■ | | | ■ | ■ |
| SK5 | ■ | ■ | | | | |
| SK6 | ■ | ■ | | ■ | ■ | ■ |
| SK7 | | | | | ■ | ■ |
| SK8 | ■ | | | | ■ | ■ |
| SK9 | ■ | ■ | | | ■ | ■ |
| SK10 | | | | | | ■ |
| SK11 | | | | ■ | ■ | |
| SK12 | | ■ | | | | |
| SK13 | | | | ■ | | |
| SK14 | ■ | | | | | |
| SK15 | | ■ | ■ | ■ | | |
| SK16 | | | ■ | ■ | | |
| SK17 | | ■ | ■ | ■ | ■ | |
| SK18 | | | | ■ | | |
| SK19 | | ■ | ■ | ■ | | |
| SK20 | | | ■ | ■ | ■ | |
| SK21 | | | | | ■ | |
| SK22 | | | | ■ | | |
| SK23 | | | | ■ | | |
| Total | 7 | 8 | 6 | 13 | 12 | 8 |

Figure 2: Skills required in each phase.

ted situations that help them gain the necessary expertise to act in each case. To be truly useful, the case studies must also meet some requirements. First, the cases must be coherent and resemble a real situation: they have to make sense and provide correct input for the students to practice with. Second, the cases have to present a complex context to the students. If they are confronted with an ideal and simplified situation they are not going to be ready to face a difficult one. Finally, they have to evolve in time as real enterprises do in response to regulations, market and technology changes.

In order to provide cases that cover all the requirements cited above, we created the IT Laboratory as a set of reality simulated scenarios in different business verticals. This laboratory has been used for six years as the main tool in more than ten graduate and undergraduate courses and for hundreds of students. The next two sections present the processes for creating and using scenarios in the laboratory.

## 4 IT LABORATORY

The IT Laboratory is based on a solid and flexible infrastructure capable of supporting a set of virtual companies belonging to different business verticals, which pose architectural challenges that students must understand, analyse, and solve. The laboratory was created with the purpose of giving the students of different IT programs the opportunity to interact with reality simulated cases in a controlled environment. In this environment, training is complemented from the experience, in addition to the theoretical knowledge acquired. This approach can be used in undergraduate, graduate or business education, changing the size and difficulty of the assignments accordingly. These virtual companies or cases are called

Table 1: Skills required by an IT architect.

| ID | SKILL |
|---|---|
| SK1 | Analyze and understand problems, requirements and constraints |
| SK2 | Design, document and justify proposed solutions |
| SK3 | Build, implement, operate and manage designs |
| SK4 | Manage IT projects |
| SK5 | Work in multidisciplinary teams |
| SK6 | Work with other IT roles |
| SK7 | Recommend implementation projects prioritization |
| SK8 | Guarantee quality in IT |
| SK9 | Lead work teams |
| SK10 | Communicate business and IT concepts |
| SK11 | Give value to business through IT |
| SK12 | Understand the organizations business |
| SK13 | Align business and IT |
| SK14 | Define business projects scope |
| SK15 | Manage software |
| SK16 | Design software |
| SK17 | Develop business strategies |
| SK18 | Define the IT architecture |
| SK19 | Optimize business capabilities |
| SK20 | Manage the integration and reuse of existing elements of the EA |
| SK21 | Design solution architecture |
| SK22 | Integrate technologies |
| SK23 | Give recommendations regarding to the appropriate solutions for specific problems |

*scenarios* and they are divided in two groups: *conceptual scenarios* and *operational scenarios*.

*Conceptual scenarios* are composed by business, information, application, and technology models but without a real implementation to simulate its operation. *Operational scenarios* have a real technology solution in which students can work and implement IT architecture projects. An operational scenario implementation consists on a set of virtual servers supporting enterprise components like Enterprise Service Bus (ESB), Enterprise Resource Planning (ERP), Customer Relationship Management (CRM), and Business Process Management Suites (BPMS) , as well as other custom made software applications. The underlying infrastructure recreates the software and hardware capabilities of a big or medium company. This infrastructure is composed by virtual machines with varying technology capabilities. Those virtual machines are hosted in a medium available datacenter.

Currently, the IT laboratory has more than thirty virtual machines, 1.5 TB of storage, 228 GB of memory and 2.8 GHz of processing power. It also has web pages describing the scenarios and has served as an experimentation environment for more than ten different students cohorts in three different programs. An model describing the deployment of one particular scenario is shown in Figure 3. This model shows the supporting servers for an IT implementation, divided into front-end and back-end. The first group represents the servers's hosting components that directly accesed by the users. The second one represents all the servers in charge of different functions and operations that do not have direct contact with the users. Additionally, there are components that do not belong on either group, since they are servers responsible for hosting auxiliary services such as load balancing and redirection.

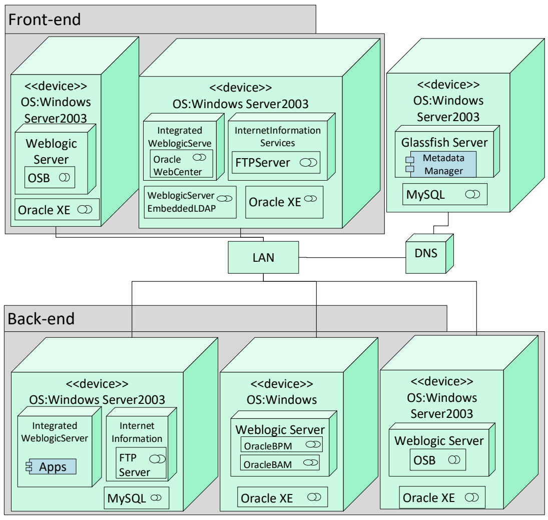

Figure 3: Scenario deployment model.

Nowadays, our laboratory has 11 conceptual scenarios and 3 operational scenarios in diverse industries and with different contexts. Figure 4 shows the distribution of the different conceptual and operational scenarios. As it was previously exposed, there is a clear difference between the components in conceptual and operational scenarios. That difference impacts the type of students that use the scenario and likewise the projects they have to face. Conceptual scenarios do have an architectural documentation the undergraduate students can review, use and change in order to develop the first five phases of an IT architecture project. However, because of the courses's level and objective, they do not implement or modify any solution. On the other hand, graduate students can use the operational scenarios to face complex and complete IT projects in order to complement their education.

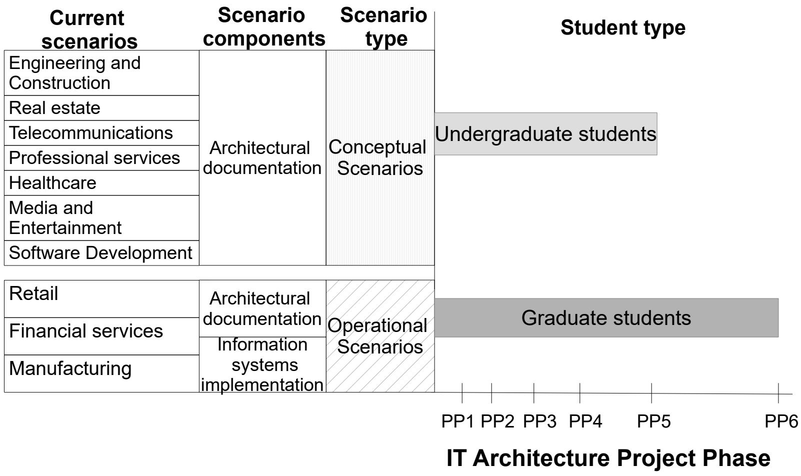


Figure 4: IT Laboratory Distribution.

## 4.1 Operational Scenarios

An operational scenario is defined as a company in a specific industry vertical. It is developed by a group of *scenario builders* with the help of industry experts who help by gathering information and validating some of the subsequent steps. A scenario is mainly composed by two elements: an IT Architecture documentation and an IT solution. The first one consists mainly on the artifacts (models and documentation) related to the four IT architecture domains (business, information, application and technology). The IT solution refers to the software and hardware components needed to support the defined ITA. The process for creating an operational scenario follows a specific methodology which is showed in Figure 5 and explained step by step in the following subsections.

### 4.1.1 Context

Once the industry for the scenario is selected, the first step consists in acquiring background information about the industry. Scenario builders thus research the business vertical, and in particular, they look for industry's benchmarks which consists of key indicators, drivers, and comparisons of how companies perform relative to their competitors. This information gives them solid foundation about the vertical and the most important indicators, motivators and challenges a company on that industry has to endure. Moreover, they look for similar organizations to learn more about its typical operation, resources and customers. Lastly, they have interviews with industry experts. All this information helps scenario builders get a deeper understanding about the typical processes, infrastructure and day to day operation of that industry.

### 4.1.2 High-level Design

With a more profound knowledge about the business vertical, scenario builders start a high level design of the four domains of IT architecture: Business Architecture, Information Architecture, Application Architecture, and Infrastructure Architecture.

In each domain, they design a number of critical models. After they are completed, there is a checkpoint with industry experts to validate if the architects work is correct and accurate. The typical step after the validation is adjusting and refining the models, and assuring compliance with the prime requirement of a utile case: coherence. Then, scenario builders perform a Strengths, Weaknesses, Opportunities, Threats (SWOT) Analysis in order to identify future transformation-drivers for the company.

During these steps, scenario builders also have to assure that the design shows a high complexity level. Thus, the scenarios require big business models, many bussiness processes, and a great number of applications, among others. Furthermore, the simulated company may have to be imperfect as any real company is, presenting problems and inefficiencies. This makes the scenario compliant with the second requirement of useful case studies.

### 4.1.3 Detailed Design

Taking the high level design as a base, scenario builders can start constructing more specific architectures: process architectures and solution architectures. The first one, starts with the previous bussiness models and delves into the macro-processes of the value chain. For each macroprocess, scenario builders design and model the processes and subprocesses that

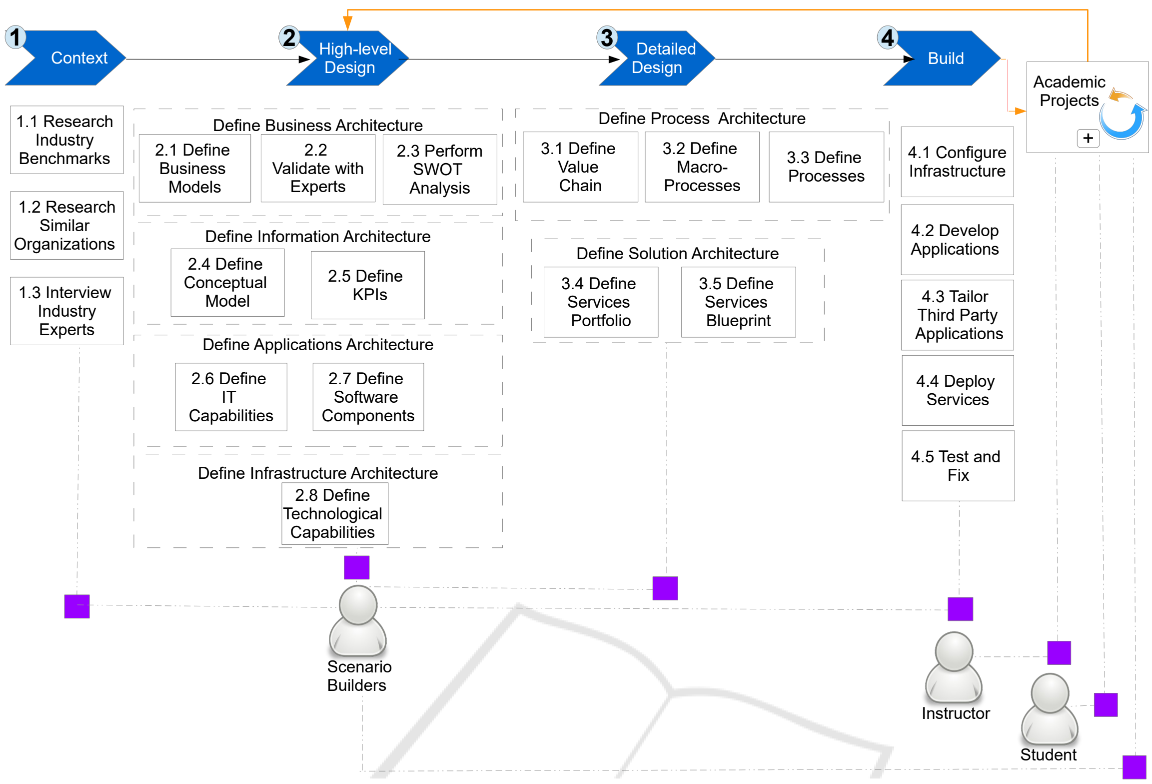


Figure 5: Scenario Creation Methodology.



support or facilitate the company's operation. The second one, accommodates the application, information, and technology layers of the company including the service portfolio and the integration blueprint. The services portfolio organizes all the services the IT solution has to offer in order to support the bussiness and the integration blueprint shows shows the interactions and the nature of these interactions in between the IT solution components.

### 4.1.4 Build

With all the previous definitions, scenario builders start building code for each software component, expose the services, test them and, once finished, install and deploy the components on the infrastructure acquired for the scenario. When scenarios are completed they become useful for different courses and and following their completion the Academic Projects phase showed in Figure 5 begins. This phase is expanded in Figure 6.

### 4.1.5 Initiative Definition

We define an *initiative* as a business transformation driver the student must materialize into real changes in the company business and IT components through a project. Choosing the initiatives is a complex task because they have to be consistent with the company's environment and assure that during their development students integrate the knowledge acquired on theoretical classes and develop correct skills. Therefore, the instructor has to do several activities before selecting a good initiative.

In order to identify possible initiatives, the instructor uses the SWOT analysis and looks for possible actions to exploit an opportunity, eliminate a weakness or mitigate the impact of a threat. Moreover, the instructor analyzes the company as a whole, taking into account external and internal forces that may affect its operation. This leads to other possible initiatives. Once the possible initiatives are written down, it is necessary to perform an evaluation to prioritize and select the best ones. For the evaluation there are two main criteria: the architectural effort, including skills involved, and the estimated time to develop the initiative. For the former one, the definition of the skills required in each IT project phase that was introduced in section 2 is used.

The instructor estimates the effort points by measuring how much dedication each candidate initiative requires in the different phases of an architectu-

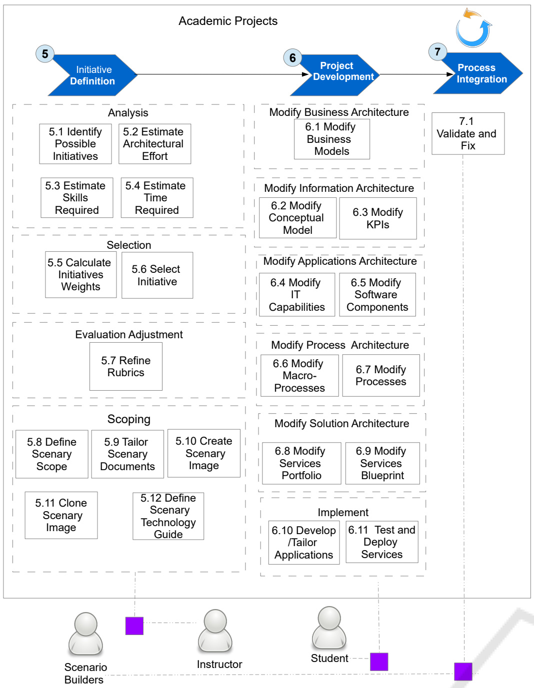


Figure 6: Academic Projects phase.

| | PP1 | PP2 | PP3 | PP4 | PP5 | PP6 | Total |
|---|---|---|---|---|---|---|---|
| Skills ponderation | 3 | 2 | 1 | 1 | 2 | 6 | - |
| I1 | 3 | 1 | 3 | 1 | 3 | 5 | - |
| Points | 9 | 2 | 3 | 1 | 6 | 30 | 51 |
| I2 | 5 | 1 | 1 | 5 | 3 | 5 | - |
| Points | 15 | 2 | 1 | 5 | 6 | 30 | 59 |

Figure 7: Architectural Effort Calculation.

ral project. By dedication we refer to the time and level of expertise expected to complete the tasks of each phase. Then, the instructor calculates the weight of each initiative by multiplying the effort points in each phase of the project with the skills needed in that phase. Each of the final values from the different phases are finally summed to get the final architectural effort required to complete the initiative. These operations can be appreciated on Figure 7.

After that, the instructor contacts a group of instructors and experienced IT architects to perform an expert's judgement to judge the approximate time that each initiative would take to be completed. Candidate initiatives are then prioritized: the most eligible ones are those with a high architectural effort but with a 4 month or less time frame, period in which the projects will take place. The instructor then selects one which meets the stated criteria.

Once the initiative is selected, rubrics with the evaluation criteria are refined, detailing which of the project phases are the most important and therefore deserve a greater weight on the student overall marks. Additionaly, instructors select the documentation that students need in order to understand the company and make the initiative real. Also, copies are made of the virtual machines hosting the scenario implementation. There has to be a copy for every team of students working on the project course, including a deployment guide and information about the technologies in which the scenario is based on.

### 4.1.6 Project Development

During the project development stage, the students have to go through the phases of an IT project in order to design and build the business an technology capabilities required to materialize the initiative. Depending on the initiative, changes will be required in the different architectural domain models. For example, if we are talking about creating a whole new sales channel, there could be more modifications to the models than if we are talking about altering some processes. Then, in order to correctly construct the initiative, students must follow some or all the stages of the process for an IT architecture project as stated in section 2.

### 4.1.7 Project Integration

The key to having a reliable and self-sustainable scenario lies in this step because scenario builders can take the work done by the students, revise, adjust and add it to the scenario. Basically, scenario builders study the works done by the students and select the best ones. Then, after some modifications or adjustments, they integrate the new components to the scenario. This process assures the last requirement of a useful case: evolving in time as the scenario is always changing and improving.

## 5 CASE STUDY: ECOS

The Software Construction Specialization (ECOS) is a postgraduate program at Universidad de los Andes oriented towards information technology professionals who want to acquire an architect profile. The program combines seven theoretical courses and three integrator projects (see Figure 8). The first ones give students the foundation and concepts of the best practices in enterprise software construction. The projects provide a space in which students can apply their knowledge in the development of different stages of an IT architecture project process.

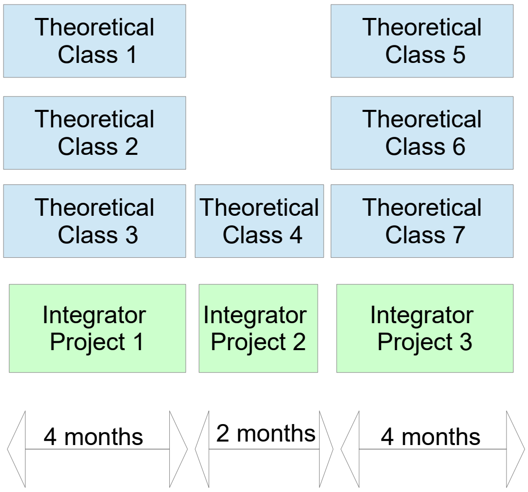


Figure 8: ECOS main structure.

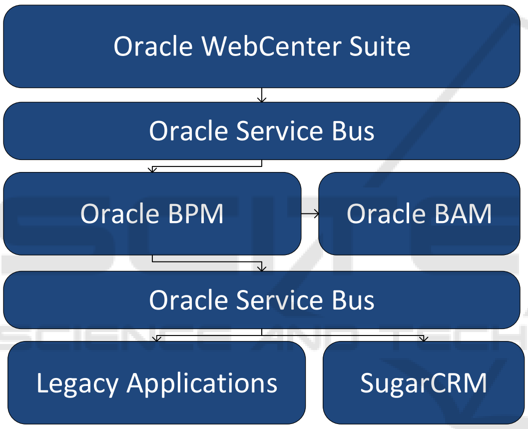


Figure 9: MPLA Components Model.

In ECOS' projects, the IT laboratory is a key tool as it provides scenarios for the students to work. The scenario which has been used for the last six years is the Marketplace of the Alps (MPLA), a fictional scenario representing a marketplace between common goods retailers and manufacturers. The rest of this section shows a brief description of the MPLA scenario, the way ECOS used it during the past four years, and an evaluation of the laboratory.

## 5.1 The Scenario: MPLA

Marketplace of the Alps is a company which provides a virtual system where different retailers can acquire products from a variety of options given by manufacturers or suppliers. Manufacturers offer their products, retailers specify what they want to buy and MPLA manages the transactions between them. The operation of MPLA revolves around four types of transactions:

PRICAT: Replicate product catalog (commercial supply) of a particular manufacturer to all retailers registered in MarketPlace that are interested in buying the product.

PO (Purchase order): Receive orders from a particular retailer and direct it to a specific set of manufacturers. The purchase order should only consider products for which the retailer has expressed interest in acquiring.

DA (Dispatching Advice): Receive notification of release, in response to a purchase order. This notice is sent from the manufacturer and is routed to the retailer which generated the PO.

RMA (Return Material Advice): Receive messages of merchandise return from the retailer and direct it to the manufacturer who made the delivery of the products (DA) to that entity.

The business model that supports the MarketPlace today is quite simple: Retailers generate a purchase order (PO) to the MarketPlace. The order mainly has: the desired product, maximum delivery date and maximum date associated auction duration. Then, the MarketPlace routes the order to all manufacturers who offer products that can fill the order. A reverse auction associated with the PO is created in order for the manufacturers to bid on. In the reverese auction, the manufacturers make their offers and the bid with the lowest price that meets the delivery date requested by the retailer is selected as the winner. Then, both the winning manufacturer and the retailer are notified and the manufacturer proceeds to generate a dispatch to the retailer.

MPLA's operation is totally based on different technology solutions. These solutions are mainly provided by Oracle Technologies and its integration is made through web services. MPLA's technology solutions architecture and Business Model are shown in Figure 9 and Figure 10 respectively.

## 5.2 Usage

In ECOS, projects start with the definition of initiatives. As it is a graduated program, initiatives must present hard challenges and may involve the development of all the IT architecture project steps. The steps the students have to perform in the project are divided into three courses thoughout a year (Project 1, 2, and 3) as shown in Figure 11.

To exemplify the initiatives selection, Table 2 presents the candidate initiatives identified by ECOS instructors on 2014. All of them were evaluated to determine the effort needed to materialize each one.

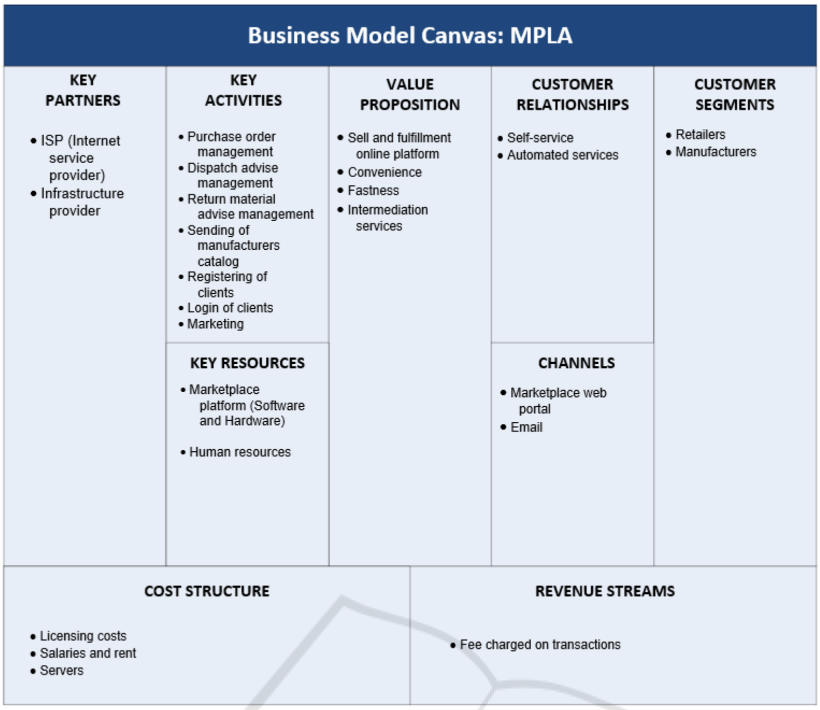


Figure 10: MPLA Canvas Model.



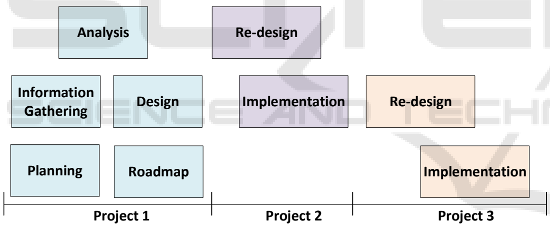


Figure 11: Project integrator courses distribution.

This evaluation was made by 4 ECOS instructors and then summarized. Then, taking those results and the skills required by each phase calculation, the architectural effort was determined, as it is shown in Figure 12.

Table 2: Candidate initiatives.

| ID | Initiative |
|---|---|
| I1 | Customer knowledge improvement |
| I2 | Reputation based selection |
| I3 | New mobile app |
| I4 | Marketing campaigns |

After that, the instructors performed the expert's judgement with the purpose of making an estimate of the time the students will need to complete the initiative. Then, taking the architectural effort and the average time determined by the instructors, the best

| | PP1 | PP2 | PP3 | PP4 | PP5 | PP6 | Total |
|---|---|---|---|---|---|---|---|
| Skills ponderation | 7 | 8 | 6 | 13 | 12 | 8 | |
| I1 | 3 | 5 | 3 | 5 | 5 | 5 | |
| Points | 21 | 40 | 18 | 65 | 60 | 40 | 244 |
| I2 | 1 | 5 | 3 | 3 | 3 | 3 | |
| Points | 7 | 40 | 18 | 39 | 36 | 24 | 164 |
| I3 | 5 | 5 | 5 | 5 | 5 | 5 | |
| Points | 35 | 40 | 30 | 65 | 60 | 40 | 270 |
| I4 | 1 | 3 | 5 | 3 | 3 | 3 | |
| Points | 7 | 24 | 30 | 39 | 36 | 24 | 160 |

Figure 12: Architectural Effort.

| Initiative | Architectural Effort | Estimated Time |
|---|---|---|
| I1 | 244 | 6 months |
| I2 | 164 | 5 months |
| I3 | 270 | 8 months |
| I4 | 160 | 4,5 months |

Figure 13: Initiatives selection.

initiative was selected, as seen in Figure 13.

Then, the documentation and virtual machine copies were given to the thirty students divided in six groups. They started Project 1 reviewing and gathering additional information of MPLA in order to start making the analysis, design and roadmap phases correctly. Parallel to the time of Project 1 the students were also acquiring knowledge and useful concepts in their other courses which could be applied to the stages of the project. During Project 2 they were faced with the scenario implementation which has the components presented on Figure 9. During this, a tutorial was provided to the students in order to familiarize them with the scenario's technologies. They were also allowed to refine the design and roadmap defined in Project 1. Finally, in Project 3 the students made the modifications to the legacy applications and enterprise systems in order to develop their designed customer knowledge improvements.

## 5.3 Evaluation

The evaluation of the IT laboratory was made in two ways. The first one was the continuous evaluation with the experts to validate coherence and pertinence of the built scenarios. This first evaluation was executed regularly as the IT laboratory was modified regularly. The second one was the IT laboratory impact on ECOS students. As we stated that the IT laboratory may facilitate the IT architects training and provide an environment in which students can get closer to an ITA project real experience, it is therefore necessary to measure students improvement on the academic and professional fields. For measuring this, we took three different indicators: the improvement of their marks along the courses; the program satisfaction surveys, and alumni surveys. We made our assessments in four different cohorts of the students of our program.

### 5.3.1 Marks Improvement

In this indicator we measured progress across the stages of the project, using the three integrator projects as check points. On each checkpoint, students must be faced with a stakeholder meeting and present their results as they would do in front of the customer. This stakeholder meeting is composed by industry experts and instructors who give the students feedback and state needed modifications. We found that the first check point is usually hard on the students as it is composed by the analysis and design steps and they usually have a freat deal to modify and improve. The second one is a refining of the previous step and a first approach to the implementation so they usually have a rough start on it too.

Finally in the last integrator project they have to finish the refinement of the design and complete the implementation. It is clearly the hardest iteration of the project but as they have previously worked on the design and implementation, and at that point they have learned more concepts from theoretical courses in the specialization, they usually improve their results at

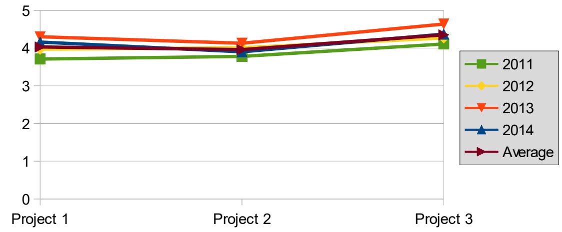

Figure 14: Marks improvement.

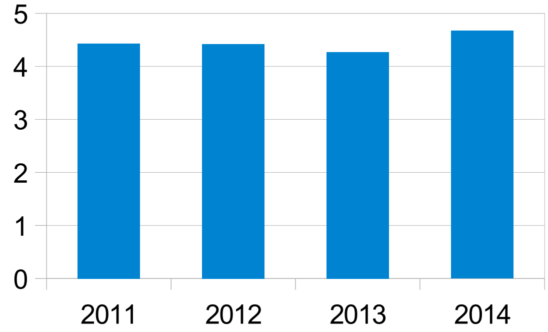

Figure 15: Average qualification satisfaction surveys.

the end of this phase. Results of this evaluation performed yearly during four years of the specialization with student groups of about forty people are shown in Figure 14. We can see a growing model through the results of the first checkpoint and the last. These results help us understand if the continuous practice benefits the students performance on an ITA projects development according to the experts opinion.

### 5.3.2 Satisfaction Surveys

Another relevant indicator we considered was the student's perception of the entire specialization program. For that we sent students satisfaction surveys at the end of each individual course during the same four years of the previous indicator. Measuring each course gave us the possibility to adjust courses individually and also made an average in order to know the student's opinion on the program.

In the surveys we asked students to give a qualification from 1 to 5 according to how satisfied they were with the different courses; measuring contents, instructors, materials and of course the IT laboratory as the main course's support. We found that the general perception was undoubedly good as the results from the four year period were high (See Figure 15).

### 5.3.3 Alumni Surveys

As exposed previously, our intention is to generate professionals better suited for the real life projects. So, in order to find out if we were really making a

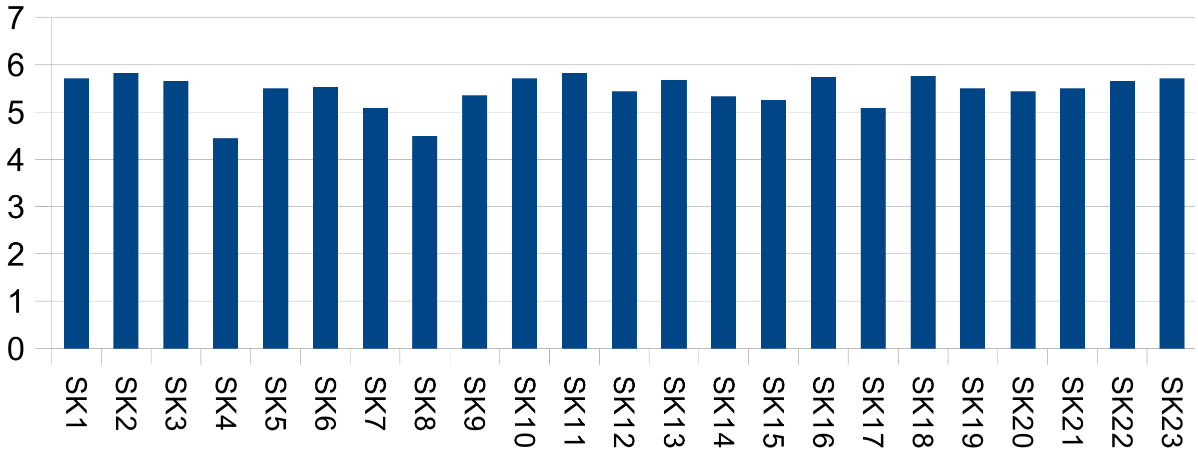


Figure 16: Answer to question: Indicate from 1 to 7 how much the following skills strengthened during your passing through the program, where 1 implies that you did not develop the skill and 7 that you developed it completely.

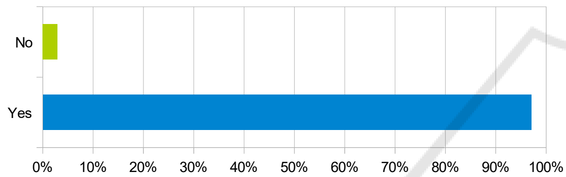


Figure 17: Answer to question: Do you think that during the courses Project 1, Project 2 and Project 3 you applied the concepts acquired in the other program's courses?

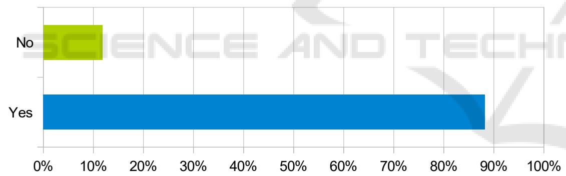


Figure 18: Answer to question: Do you think that the use of a tool like the IT Laboratory was useful for your education?

change in our students's professional life, we questioned our alumni. Here are the results of the most important questions as answered by 35 ECOS alumni students (Figures 16, 17 and 18). As we can see, the surveys show a positive impact and a high development of the desired skills, proving the pertinence of the approach. Nonetheless, we are going to continue improving it in order to get even better results, have more reality simulated cases and help train more students.

## 6 CONCLUSIONS

This paper addresses the difficulty of complementing the training of IT architects with practical exercises and not only theoretically. Given that it is unlikely that the architects in training put their knowledge into practice in real companies, it proposes the creation of an IT laboratory that recreates real companies. These virtual companies called scenarios have bussiness and IT components and they give students an environment to practice and reinforce their abilities in the development of ITA projects.

For the scenarios to be useful to students, they have to meet three requirements: coherence, complexity and evolution. With this objective, the paper explains in detail how during the scenario's creation there have to be industry experts involved who can evaluate the consistency of it according with its industry and size. Moreover, the scenarios creation process takes into account the insertion of imperfections and inconsistencies like the ones in real companies. Finally, during the scenario's usage, it is explained how they were given feedback and new components in time.

Then, the scenarios are useful for students working in projects that integrate the use of theoretical concepts. This approach was evaluated in a postgraduate program named ECOS during four consecutive years. During that time the combination of theoretical courses and practical projects based on the IT laboratory was evaluated. The evaluation was focused on three aspects: grades improvement, student satisfaction and impact on graduates. All these evaluations yielded positive results, proving that the approach facilitated the acquisition of the skills necessary for an architect to face real projects.

In conclusion, practice is essential in the training of architects, but in order for it to be effective, it must be done in contexts that present adequate challenges for students. In this sense, the creation of complex virtual scenarios supported in real technology and with a complete business definition, can be an alternative of high impact and effectiveness. This continuous practice can have a huge impact on IT architects's training as it reduces the timeframe needed for a professional to acquire the insight and skills for executing and IT Architecture project.

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