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Teaching Professional Skills to Engineering Students with Enterprise Resource Planning (ERP): an International Project*

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The engineering education community has long recognized that graduates not only need to possess sound technical knowledge in their chosen disciplines but also need to be better educated in the areas of communication skills, teamwork, leadership and other professional skills. Despite the recognized importance, it is not easy to develop and implement a curriculum that fosters such skills. Also subsequent outcome assessment of the achieved skill levels poses many challenges and demands much creativity. This paper describes a joint experience between Syracuse University in USA and Carlos III University in Spain. The experience shows that an industry-scale ERP solution can be used to develop professional skills for engineering students and improve academic curricula. Although ERP solutions have been used in higher education, this is probably the first time that an ERP system is utilized primarily for fostering professional skills. Findings from this experience are discussed as well as several opportunities for further development.

Keywords: ERP, global economy, international collaboration, professional skills.

INTRODUCTION

VARIOUS CONSTITUENTS of engineering education including the industry, the educators, and the graduates agree that engineers not only need to possess sound technical knowledge in their respective disciplines, but also need to be better educated in the areas of professional skills such as communication skills, teamwork and leadership. As an effort to enhance the professional skills for engineering students, the Accreditation Board for Engineering and Technology (ABET) in USA now requires a set of six outcomes of the professional skills in its new program criteria EC2000 [1]:

- an ability to function in multi-disciplinary teams;
- an understanding of professional and ethical responsibility;
- an ability to communicate effectively;
- the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context;
- a recognition of the need for, and an ability to engage in life-long learning; and
- a knowledge of contemporary issues.

The impact of the new criteria set out by the ABET has been far reaching and significant in making the engineering community aware of the importance of the professional skills and promoting their actual implementation in engineering curricula.

This milestone is preceded by numerous publications by various professional organizations:

- The ASEE's (American Society of Engineering Education) *'Engineering Education for A Changing World'* stated that engineering education programs must be relevant, attractive, and connected, preparing students for a broad range of careers and lifelong learning [2].
- The NSF's (National Science Foundation) *'Restructuring Engineering Education: A Focus on Change'* recommended that engineering education should become flexible enough to support diverse career aspirations and engineering courses would include a broad range of concerns such as environmental, political and social issues; international and historical contexts; and legal and ethical ramifications [3].
- The NRC's (National Research Council) Board of Engineering Education also urged for curriculum reform including early exposure to 'real' engineering and more extensive exposure to interdisciplinary, hands-on, industrial practice aspects, team work, systems thinking, and creative design [4].
- SME (Society of Manufacturing Engineers) identified fourteen competency gaps desired by Industry but missing among the newly hired graduates [5]. As a result, SME called for closing gaps in communication skills, teamwork, personal attributes, project management, business

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skills, change management, and continuous or lifelong learning. Shuman et al. provides a detail account on the evolution of the importance of professional skills in engineering and science over the last 50 years [6].

The recognition of the importance of professional skills in engineers is not restricted to the United States of America alone. In Europe, a new European Higher Education Area (EHEA) is currently under development. This project, launched by the Bologna Declaration on June 19th 1999, intends to articulate a new European higher education system by year 2010. The new European higher education system will provide a common protocol to ensure comparable levels of quality in higher education. By doing this, mobility and exchange of students, scholars and other university professionals will be significantly enhanced.

As a part of EHEA development, university degrees in European countries are being redesigned. In Spain, academic committees have been created to advise on the contents and titles of the degree programs. Publications by these committees stress the importance of fostering professional skills in engineering education. For example, an educational objective of a degree program in information technology engineering is to pursue the 'scientific, technological and socio-economic education of all IT professionals' [7]. In order to achieve the objective, IT engineers are to be provided not only with basic and applied scientific and technical skills, but also with economic/management skills and social/humanistic skills. Consequently, the IT professionals will be able to develop effective oral and written communication skills and command of foreign languages. They will be acquainted with the main regulatory characteristics of their professional environment and will be aware of the social and ethical dimension of their activities. Design guidelines for other engineering degree programs such as civil and computer engineering include similar statements on the importance of professional skills.

Despite the global awareness of the importance of professional skills, developing and implementing a course or a curriculum that fosters such skills has not been a trivial task to the engineering education community. Shuman, et al., indicate that such challenges are due to three factors [6]:

1. The definitions of the professional outcomes, which are not as clear nor as widely accepted by the engineering education community as the 'hard' outcomes.
2. The scope by which the outcome is assessed.
3. The nature of the outcome itself.

Despite numerous examples of innovative approaches to address the issue of teaching professional skills throughout a course or a curriculum, design of outcome assessment of the achieved skill levels poses additional challenges and demands much creativity [6, 8].

This paper presents an idea and experience of utilizing an industry-scale Enterprise Resource Planning (ERP) system to foster professional skills for engineering students. The experience is based on a collaborative educational project between Syracuse University in USA and Carlos III University in Spain which occurred during 2004 Fall semester. Although ERP solutions have been used in higher education, this is probably the first that an ERP system has been utilized primarily for fostering professional skills. Some very positive results have been found. As the participating students had not met nor had been meeting face to face throughout the project, the experience and findings reported in this paper may be modeled as an alternative to typical on-site international collaboration projects.

The professional skills can mean different things to different people and there is no clear consensus on what constitutes the professional skills. However, in this paper, we adopt ABET's definition as a part of its accreditation criteria. They are, as Shuman et al. have classified:

1. *A set of process skills:* a communication skill and an ability to function on multi-disciplinary teams.
2. *A set of awareness skills:* an understanding of professional and ethical responsibility; an understanding of the impact of engineering solutions in a global, economic, environmental, and societal context; a recognition of the need for, and an ability to engage in life-long learning; and a knowledge of contemporary issues.

Our experience reported in this paper in particular deals with three professional skills:

- an ability to communicate effectively
- an ability to function on multi-disciplinary teams
- an understanding of the impact of engineering solutions in a global, economic, environmental, and societal context.

ERP AND HIGHER EDUCATION

An Enterprise Resource Planning (ERP) system is a generic term for an integrated enterprise computing system. It is a customized-packaged software-based system that attempts to integrate various functions in an enterprise such as finance, accounting, materials management, production management, human resource management, etc. It is a software architecture that facilitates the flow of information among all functions within an enterprise.

The importance of the ERP system in the current business environment justifies the increasing adoption of ERP systems in university curricula since there is a growing need for educating people who are affected by the new system [9]. Implementing an ERP system costs much and

takes a long time. Typically, it costs between 15 and 50 million dollars and takes 9 months to 2 years to implement [10]. Therefore, companies want to ensure a better return-on-investment even after a successful implementation of an ERP project. One of the reasons why the ERP implementation costs that high is that the process often involves the business process reengineering of the participating companies. In other words, a large-scale corporate-wide organizational change often goes together with the ERP implementation. Firms have a chance to review and reengineer their entire business processes and such a change can impact every corner of the company and virtually all the employees are affected. This will involve education of the value of ERP systems to all the users in the company.

Recognizing the importance of the ERP systems, many university programs have adopted the ERP system in their curricula with varying degrees of educational and research objectives. For example, ERP is frequently used to expose students to the real world from the classroom or to develop a computer-based business simulator [11]. One popular option is the use of ERP systems as an integrative teaching tool. Over the last decade, management schools have been criticized for delivering management education through sets of semi-independent subjects, each of them focusing on an isolated management area or business function [12]. Such an approach inevitably provides a narrow perspective of the organization to the students and does not prepare them well in addressing difficult and hard structured problems whose solution often requires a multidisciplinary view [13]. To sum up, this functional stovepipe oriented approach fails to prepare the students in order to cope with some of the main challenges of today's competitive environment. A number of business schools have realized the advantages and potential of using the ERP systems and integrated business curricula across functional areas [14–18]. A few engineering schools have also incorporated ERP systems into their curriculum [19–22].

The ERP use in every institution is unique depending on their educational objectives and needs. Watson, et al. [23], provide a list of common issues that need to be addressed when an institution decides to adopt an ERP system for educational purposes:

- which aspects of ERP are emphasized;
- which programs/departments support the project;
- how ERP is actually used in existing programs;
- which students are affected (undergraduate, MBA, business, engineering, computer science);
- how extensively ERP is used;
- how many faculty members are actually involved in the ERP project.

There are several challenges associated with the use of the ERP system for academic purposes. First of all, the comprehensiveness of ES within an enterprise suggests that ES education should be rather comprehensive. As a result, the notion that ES education can fit comfortably within a single discipline is perhaps not realistic. While transactions, sub-modules and single modules can be taught in one unit, a focus on the entire ES solution, on industry solutions or extended ES requires multiple ES-related units and the necessary integration of these offerings.

Another hurdle is developing a plan that would integrate the software into the curriculum without resulting in only training students in the use of a software package. First, the students must be taught enough about the software package to use it comfortably. Second, the focus should be on problems created by the cross-functional process and solved by the software. Finally, the amount of time needed to develop new course materials has to be managed.

The setup cost of engaging in an educational ERP project is relatively high including hardware & software fee, technical support and faculty training. Once the project is launched, a considerable level of faculty commitment is required in order for the ERP initiative to survive over time.

Despite these challenges, significant progresses have been made in university curriculum and teaching materials [11]. We believe the inherent complexity of the ERP system provides an ideal environment for fostering a number of professional skills when the ERP system is utilized judiciously.

ERP EDUCATION AT SYRACUSE UNIVERSITY AND CARLOS III UNIVERSITY

ERP education at Syracuse University

At Syracuse University, the ERP-related activities began with education and research in manufacturing engineering. Recognizing the interdisciplinary nature of manufacturing, an umbrella unit called the Institute for Manufacturing Enterprises was established in 1999 with the mission of promoting learning in manufacturing enterprises through teaching, application, integration, discovery and service. The IME is a multi-disciplinary research and education center partnering with manufacturing companies as well as the College of Engineering and Computer Science, the School of Management, the School of Information Studies, the University College, and other schools and colleges at Syracuse University [19].

The operating principles of the IME are:

- *Connectivity.* Making seamless connections within academia and between academia and industry, which is an essential component of learning in manufacturing enterprises.
- *Lifelong learning.* Leaders in manufacturing enterprises are committed to lifelong learning,

which can be fostered by accommodating a differential rate of learning.
- *Scholarship.* Scholarship is a way of living, worthy of being embraced by everyone in manufacturing enterprises.
- *Culture for excellence.* IME is committed to achieving excellence through open dialogue, reflective listening, taking initiatives, respect-for-others, and technical innovation.

The ERP system was recognized as a practical tool to carry out the mission of the manufacturing engineering education and research at Syracuse University. In 2000, Syracuse University joined a SAP University Alliance program that allow the university community to have full access to SAP's market leading software. The SAP University Alliance Program provides a unique set of tools and community to realize the IME's vision and advance the IME's mission.

Phase 1 (2000–2002) of SAP alliance program at Syracuse University has been completed resulting in five graduate level courses with varying degrees of SAP content. These five courses are either core courses or popular elective courses for three graduate programs in the IME:

- MS in Manufacturing Engineering;
- MS in Engineering Management (on-campus version);
- MS in Engineering Management (distance-learning version).

During Phase 2 of the program (2002–2003), an 'e-manufacturing' concentration in the Manufacturing Engineering program was developed and then the undergraduate and MBA programs at the School of Management began to adopt the SAP products. In 2003, Syracuse University was recognized by SAP as a curriculum reward recipient.

The success of Phase 2 lead to Phase 3 (2003–2004), which involved more faculty and programs at Syracuse University and institutions and industry outside of Syracuse University. The industry's role has expanded significantly through the hiring of many graduates as regular employees or interns. Another significant expansion during this phase is its international collaboration. Close interactions between Syracuse University and KAIST (Korea Advanced Institute of Science and Technology) in South Korea, and Syracuse University and Carlos III University in Madrid Spain have been established.

As of January 2005, Syracuse University entered into Phase 4 by switching to a hosting service model. The SAP's University Alliance program established five University Competency Centers (UCCs) to host their members. Further collaboration with other international schools is planned during this phase.

ERP education at Carlos III University

In 1998, the Engineering Management Group at University Carlos III of Madrid (UC3M) reached a multi-year cooperative agreement with the Spanish subsidiary of SAP. Under this agreement, an on-site SAP R/3 license was provided to the UC3M, along with training and support services to be used in research and educational activities. All ERP modules were installed in a dedicated server, accessible from all faculty offices and from the PC training rooms. A multi-disciplinary group formed by full time faculty members was engaged in the SAP project. Apart from the faculty members, professional consultants from private companies also collaborated in this venture.

The main objectives of the SAP educational project were:

- to provide the students with a first-hand knowledge on a leading, industry-scale ERP solution.
- to illustrate key technical concepts embedded in the different SAP modules (for example, MRP planning in the Production Planning module).
- to teach the students the integrated, interdependent nature of the various business processes within an enterprise, as opposed to the functional stovepipe-oriented approach currently found in many Engineering Management educational programs.

In order to fulfil these objectives, a complete set of hands-on exercises was developed for different functional areas such as finance, production planning, material management, information system management, and logistics.

These exercises were linked to five main academic subjects within the Engineering Management major at Carlos III University (which encompasses the last three years of the Industrial Engineering's five-year program) and included as practical sessions within these subjects. During these years the unique first-hand experience with the ERP system has been acquired by students the Engineering Management program. This initiative has received official recognition by the UC3M as one of the Education Innovation projects in 2004.

In year 2004, the UC3M SAP educational project entered a new phase through the establishment of a multifaceted collaboration agreement with Syracuse University involving joint educational projects, faculty exchanges and research activities.

As of 2004, most Spanish universities within the SAP's University Cooperation Program had to switch to a hosted model. Exceptionally, UC3M was granted an extension of its on-site license by SAP as a recognition of its excellent use of the ERP system.

THE JOINT PROJECT

Objectives of the project

The joint project reported in this paper began on 27th of September 2004 and ended on the 29th of November 2004. The collaboration project

between University Carlos III and Syracuse University had the following objectives:

- to teach engineering students the fundamentals of the ERP system through the construction of a complete executable ERP system covering most of the major business functions, such as finance, accounting, production, sales and purchasing;
- to provide the students with a challenging environment, where they are required to build several professional skills such as an ability to function on culturally diversified teams and an ability to communicate effectively;
- to provide the students with the broad educational awareness of a global economy; and
- to develop effective assessment methods and tools for students' learning.

Students' profile and team composition

This collaboration project was a part of MFE654 (Production Systems Design and Control) for Syracuse University students while the project was an independent study for Carlos III University. The project accounted for 30% of the final course grade for Syracuse University students. A number of free academic credits were given to the Carlos III University students, which were counted towards the Engineering Management degree.

At the beginning of the experience, all the participating students were enrolled in Masters-level engineering programs such as Manufacturing Engineering, Engineering Management, Mechanical Engineering, and Aerospace Engineering. They didn't have any previous knowledge of ERP or SAP R/3 other than a general background knowledge of ERP systems.

Five teams were formed from a total of 22 students. Three teams had members both from Syracuse and Carlos III while two teams had Syracuse students only. In this way, we sought for outcome assessment comparisons between the 'international' teams (Red, Indigo, and Green) and the 'local' teams (Blue and Orange). In this paper, therefore, the international teams refer to those teams whose members were physically residing in different continents and had to collaborate remotely using additional communication tools while the local teams refer to those who could meet face-to-face if they needed to do.

Materials and communication tools

As discussed earlier, one of the biggest challenges of teaching the fundamentals of the ERP systems in Universities is to teach it as a whole, since the essence of the ERP system is its integrative nature. Bearing this in mind, the first author developed a configuration exercise lab [11] which enables the students to build an executable ERP system from ground-up. The configuration exercise was developed with the following objectives:

1. To provide students with the least possible number of exercises while exposing them to the entire range of major ERP functions.
2. To make the material lucid enough to be easily comprehensible, even by students with no prior experience in SAP R/3.
3. To enable the students to configure their own enterprise system, within 6 hours when working in teams.
4. To build a solid foundation for the students to explore additional subjects independently (such as human resources or managerial accounting functions).
5. To enable the students to perform realistic business process simulation.

The whole exercise consists of 180 exercises and is organized into 6 departments:

- Financial Management
- Production Management
- Supply Management
- Sales Management
- Controlling
- Configuration Support.

The developed configuration exercises have been used successfully in numerous engineering and business schools in USA, Spain and Korea. The first page of the table of contents is provided in Fig. 1.

An important aspect built in this exercise material when used by teams is that numerous exercises distributed among different departments are mutually dependent. This implies that unless there are suitable communications between departments, the configuration exercise can't be completed.

In addition to the configuration exercise, a number of lectures on ERP systems and SAP R/3 were provided to the students by their respective instructors at the beginning of the project.

Several communication tools have been used throughout the collaboration including emails, instant messages, and web pages. For this project, we purposely chose the communication mediums that have already become a part of everyday life for the students and deliberately avoided sophisticated tools such as video-conferencing. First, we wanted to encourage the students to communicate with each other frequently and easily whenever they wanted and needed. Therefore we avoided spending any time required for setting up a communication environment. Also, this widened the possible communication duration as much as possible. Further, since the students were already very familiar and comfortable with the communication tools, they could focus on content of the project from the very beginning rather than spend some time to get familiarized with new communication tools. This was especially important because of the limited time available (about one month) for the project.

Particularly, the following communication tools were used in the project:

- A set of slides with photographs and brief personal information of each participant. This pre-

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Fig. 1. The first page of the table of contents.

sentation proved to be very effective in terms of getting acquainted to each other at the initial stage.

- A blog-format web page in which the different assignments were posted and which served as a means of communication within a team as well as among different teams. The web page was utilized as a cross-team discussion forum for the different problems and doubts that came up during the experience (see Fig. 2).
- An instant messaging system (MSN's Instant Messaging System) for synchronous communication and electronic document sharing among the team members.
- Conventional electronic mail.

The project procedure

As the first step, each team had to come up with a product with which each team's enterprise manufactures and conducts several business transac-

Fig. 2. Syracuse-Carlos III weblog.

tions. Once the product was accepted, other detail data had to be developed such as bills of material, material master, vendor master, customer master, etc. Next, each team performed the configuration tasks that laid out required information infrastructure for each enterprise. Then master data were entered into the ERP system. Finally the students verified the correctness of their system by sequencing and executing a given set of business processes. If the configuration and master data sections were completed without any error, the business process transactions would be carried out without a problem. However, students made a few mistakes; thus real communication and debugging challenges occurred at this stage. On the last day, all the members gathered and demonstrated their systems.

Each team member was assigned to complete configuration of one or two functional modules. One of the students was additionally designated as team coordinator. Working sessions were organized as follows:

- Conventional lecturing sessions to provide basic theoretical concepts on ERP systems (approximately six hours).
- Synchronized team working sessions via instant messaging. For this kind of sessions, meeting date and time had to be pre-fixed (considering the six hours time difference between Madrid and Syracuse). These meetings were always held in English, either from the university computer clusters or from the students' homes. There were nine of these meetings: each of them took approximately two hours. All the conversations held during these meetings were recorded for later analysis, review and reference.
- Individual working sessions, from home or university computer clusters, with an estimated work load of 20 hours total.
- Occasional on-line tutorial sessions with the instructors via instant messaging.

ASSESSMENT METHODS

Students' outcome assessment for the experience has been conducted. According to Shuman et al. [6], a valid method for assessing professional skills is multi-source assessment, which collects critical information on student competencies and specific behaviors and skills from several sources such as peers, instructors and the students themselves. Therefore we employed three major assessment methods:

1. Instructors' observation and assessment.
2. Students' self assessment.
3. Quantitative analysis of teamwork.

Our goal was to develop suitable assessment methods that not only were able to assess actual technical knowledge on ERP configuration but also were able to assess various professional skills.

The following materials were used to assist the assessment process:

- the recordings of the instant messaging meetings;
- the blog-format web page (which shows the comments of the students and gives an idea of their contribution to problem discussion);
- a personal diary that recorded the different individual and joint working sessions;
- a final team demonstration in order to assess the degree of functionality of the ERP configuration;
- a narrative evaluation of the project experience by each student on an anonymous basis; and
- quantitative peer-evaluation on team members' relative contributions to the project execution.

ERP AND THE PROFESSIONAL SKILLS

In this section, we explain how an industry-scale ERP system and the knowledge of ERP have been used in the project to help students to develop the professional skills. As stated in the first section, we adopted the ABET's definition of professional skills in this project. However, only a subset of those professional skills has been assessed in the project. They are:

- an ability to communicate effectively;
- an ability to function on multi-disciplinary teams;
- an understanding of the impact of engineering solutions in a global, economic, environmental, and societal context.

To assess these professional skills we mainly used three methods:

1. Instructors' observation and assessment.
2. Students' self assessment.
3. Quantitative analysis of peer-evaluation on teamwork.

The ability to communicate effectively

Effective communication skills are essential throughout the lifecycle of an ERP system ranging from project initiation, project launching, system installation, business reengineering to subsequent maintenance. By providing a realistic situation of developing an ERP system, the students were expected to enhance their communication skills. Specifically, the exercise material and the experience were designed in such a way that unless there was effective communication among team members, the configuration task could not have been accomplished. Another aspect of this project was the communication over cultural, geographical and time boundaries for three of the five teams involved.

Instructor observation and assessment

Both instructors verified that all the five teams finished the configuration exercise successfully and were able to demonstrate that their ERP system worked correctly. This fact is an ultimate testimony that students were indeed communicating effectively with each other because a minor mistake or out-of-sequence operation by just one student would have prevented the ERP system from working properly. The instructors observed that particularly the students in international teams were able to overcome communication barriers over time differences, communication channels, and cultural differences that arose during the project. For example, certain terminologies were not normally used by a group of students. As the project went on, the students agreed on common and standard terminologies and used them. Another example is the ability of the students of handling the six-hour time difference between Madrid, Spain and Syracuse, USA.

A number of students commented on their improvements in communication skills and a couple of excerpts are provided below:

> '*. . . at the beginning I just wanted to have some free configuration credits and have a wider knowledge of SAP, a very famous program in the industry. But it taught me much more. I had to communicate with foreign people and practice English which I am not that used to.*'

> '*Collaboration has been very satisfactory. In spite of the problems that we had at the beginning (such as the time difference) and the way we were going to communicate, all the problems were adequately solved.*'

Overall, the assessment process confirmed that the students' communication skills were enhanced because (i) the students were forced in a project where they had to communicate well to accomplish the given task and (ii) the students had to communicate over several barriers including time and cultural differences.

The ability to function on multi-disciplinary teams

An industry-scale ERP system requires a high level of fidelity and complexity. In general the higher the similarity of the training situation to actual working conditions (fidelity), the better the learning of the workplace is [6]. On the other hand, the more complex the exercise is, the more team skills are required by the students. As a full-scale working ERP system was adopted in the course, the students were naturally introduced to a real workplace environment, thus resulting in a very high level of fidelity. At the same time, configuring an ERP system was very complex demanding a high level of team skills.

Since the ERP system is a truly integrated information system that cuts across all the business functions in any enterprise, the students were naturally engaged in a multidisciplinary setting. The students were asked to play a role and be in charge of the workload of a specific business function such as purchase management, production management, supply management, etc. The different work assignments were closely interrelated and real collaboration and coordination

practices were absolutely required, as opposed to the individual work on a strict division of activities among the team members. Individual team members became more knowledgeable on the assigned function and were required to share their knowledge towards building a unified ERP system.

Another important component of team skills is the ability to lead the team and to follow the leader. One student from each group was designated as the team coordinator and was in charge of activities such as the gathering of the work of the different team members or the meeting coordination. The team coordinators were, in turn, asked to communicate frequently with the instructors.

Instructor observation and assessment

The instructors observed that the students learned how to function in a multi-disciplinary team by taking their own role and collaborating with other team member of different roles. The students were conscientious in following the distribution of workload by their coordinators, so were fostering their leadership and follower-ship skills. The recordings of the IM conversations show that there were a few conflicts among team members but they were able to resolve them constructively and work for the collective goals of the team.

Some of the students' comments on the teamwork include:

'Group effort is important. One step of one of the part depends on other two steps of the other part's great effort. Be careful the configuration the group make in the SAP. It will make work goes smoothly or not.'

'It's very precious. We learned how to organize different schedule, teamwork,'

'I had to learn how to configure SAP and meet a certain deadline, which was a real proof to me, as I had to work with a certain pressure and had the experience of depending on other's work. So, to sum up, what I had out of this experience was: a certain knowledge on SAP, some training in team work and in working in English, and last a experience which is very similar to a real work experience.'

Quantitative assessment of peer-evaluation of team work

At the conclusion of the project, every student who had participated in the project was asked to provide an evaluation form for assessing their team members' contributions. To ensure objective opinions, we asked the students not to identify their team members by real names. The students were told that we were interested in their anonymous opinions on other team members' relative contributions, not who was good or bad in carrying out the project. The students indicated a particular team member by a symbol then wrote his/her relative contribution to the project as a percentage. For example, if there are five members in a team and this student feels that all five members contributed equally, he/she gives 20% to each student.

The students were asked for technical contributions and overall contributions. A total 38 number of responses were collected for 19 students (3 students didn't respond). For each team member's data, we first calculated a mean. Then we calculated a standard deviation for each. Therefore if a student felt that there were equal contributions from all the team members, the standard deviation should be 0. Figure 3 shows dot plot diagram and Fig. 4 shows box plot diagram of the collected data.

Clearly, there was a distinctive difference between teamwork performance between the local teams and the international teams. At least in this collaborative project, the students in the international teams were more effective in working in a team environment than those in the local teams. The sample size of the data set is small; therefore, some cautions against definite conclusions are advised. However, several explanations are possible for such positive results. First of all, as Syracuse students were free to choose the team they wanted to join, there is a clear potential of bias. Hence, students that decided to engage in the international experience might be expected to be more patient and understanding. Second, perhaps, the excitement of working with international partners provided much needed motivations. Third, although it might seem paradoxical, limited communications might have helped the team work better in this experience. The students in the local teams were given unlimited time and bandwidth in terms of communication. However, the abundance of the communication opportunities might have distracted them. On the other hand, knowing their communications channels were quite limited, the international team members might have developed more effective and focused communication strategies.

The understanding of the impact of engineering solutions in a global, economic, environmental and societal context

It is a common belief that understanding the global, economic, environmental and societal context is a prerequisite to the understanding of engineering impact in those contexts. Sharing this conviction, an increasing number of engineering programs have incorporated international experience for their students. They are exchange programs, study abroad programs, collaborative design team experience, etc. Most of these programs, though, require face-to-face interaction with international partners with varying degrees [6].

In the project, the students from Spain and USA formed a team while they resided in different continents. Throughout the project, students were exposed to different cultures and experienced working with counterparts from other parts of the world. This is rather unique as the participating students were not required to meet in person. We believe that the more opportunities students have regarding international collaboration, the better

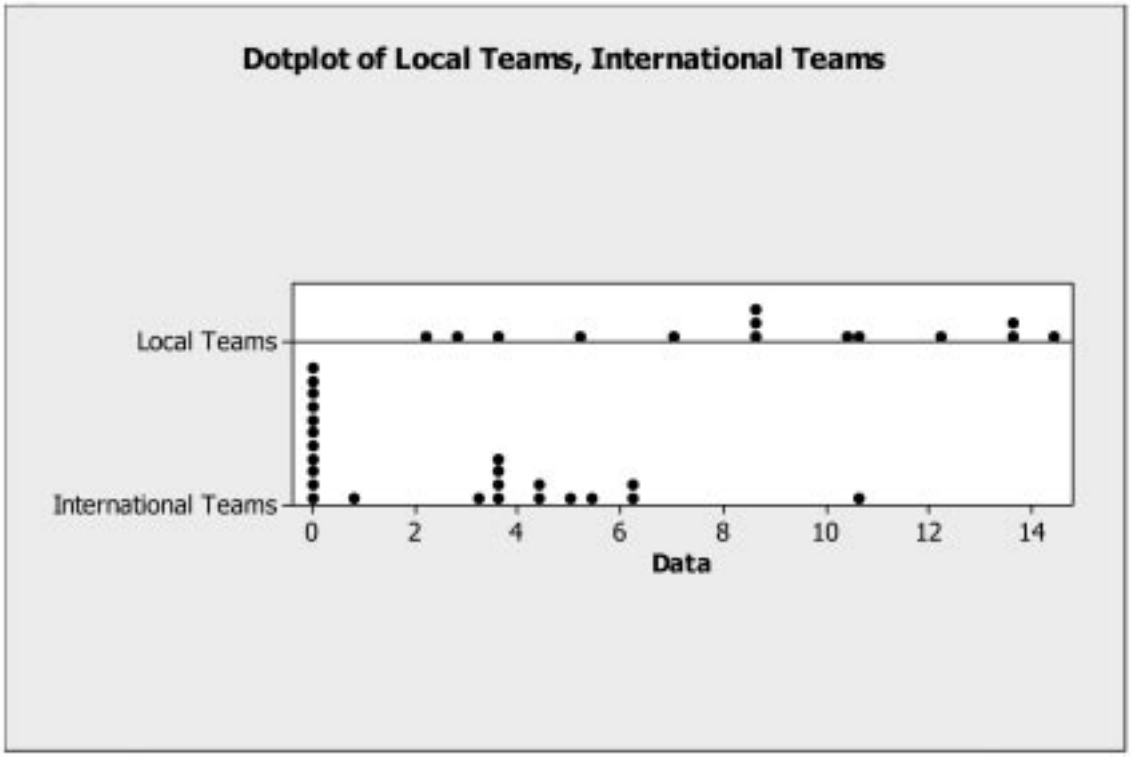

Fig. 3. Dot plot of local teams vs. international teams.

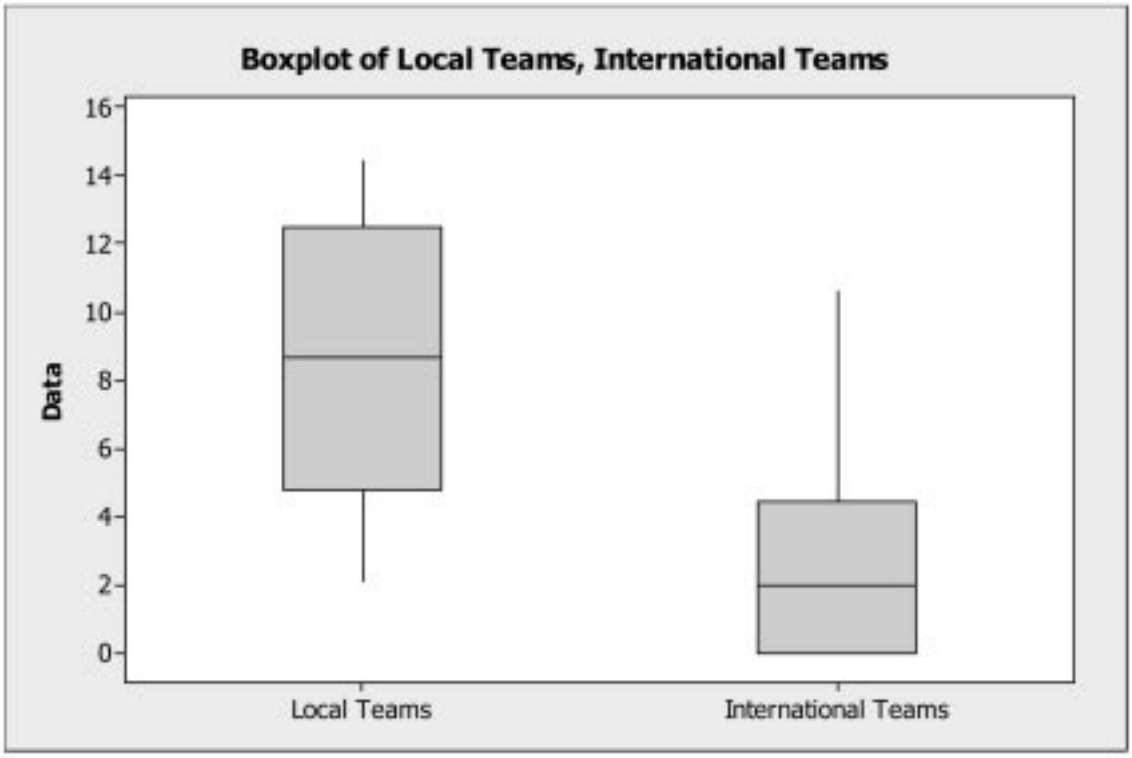

Fig. 4. Box plot of US-only teams vs. international teams.

their chances to understand global and cultural issues.

The instructors observed that the students gained significant understanding on many relevant issues such as:

- awareness of different work schedule, work habit, holiday, etc.;
- awareness of importance of ERP;
- awareness of importance of English as a world language;

- awareness of importance of respecting other cultures.

The students made the following comments:

'It was a great experience, learned a lot about Spain and its culture. And have actually stared learning Spanish, with one of my team members (Carlos) helping me out. Hope to continue the great experience that we had even further,'

'It's very precious. We learned how to organize different schedule, teamwork,'

'Although I am aware I don't have a complete knowledge of the program, I have a global vision of its possibilities. As for the relationship with my group mates, it has given me the opportunity to work with people I didn't know physically but it has not been a problem at all for conducting the work,'

'Collaboration has been very satisfactory. In spite of the problems that we had at the beginning (such as the time difference) and the way we were going to communicate, all the problems were adequately solved thanks to the good coordination of Moon and Teresa,'

'As I mentioned before this part was one of the best ones. Very useful and interesting. I tried not only build a work relationship but also to create a personal experience. I consider that collaboration with other cultures is really interesting as well as the differences in costumes and behaviour. The only thing I have to complain is that some of them didn't show up to all the meetings. Meetings tended to be short and not very productive and in the end we had to go to a personal work. Although collaboration could have been better I think that this is one of the best parts of the work and you should continue with the experience.'

DISCUSSION AND CONCLUSION

The engineering education community has recognized the professional skills for a long time and has now institutionalized the requirement through the accreditation process. However, the efficient execution and rigorous assessment process still pose considerable challenges. The collaboration experience between Syracuse University and Carlos III University illustrates an innovative example of how these challenges can be addressed.

Most of all, the experience shows that an industry-scale ERP solution can be successfully used in developing professional skills for engineering students and improve academic curricula in a cost-effective way. By performing a carefully designed configuration exercise, the students were able to improve (i) the ability to communicate effectively, (ii) the ability to function on multidisciplinary teams, and (iii) the understanding of the impact of engineering solutions in a global context.

In addition to the three main professional skills addressed in this project, other related professional skills were involved in some degree, such as the recognition of the need for lifelong learning or the knowledge of contemporary issues. For example, even though most of the students engaged in this project had a mechanical engineering undergraduate degree and no prior work experience, a number of students wanted to learn accounting upon the completion of the project. As the study of ERP solutions reveals a full set of business functions and practices, the experience apparently made the students aware of the need for additional knowledge. We are convinced that the students engaged in this project recognized the importance of lifelong learning and will pursue additional knowledge with more excitement and clearer purposes. The knowledge of contemporary issues was also fostered due to the importance of ERP solutions in today's business environment.

However, more work needs to be done regarding assessment processes [24, 25]. Although a set of suitable assessment tools and methods were developed and used in this project, most of the assessment methods were still of a qualitative nature except for the analysis of peer-group contributions. It might be worth while to investigate other assessment methodologies.

A number of recommendations were drawn from this experience. We observed that the actions taken to encourage cordial teamwork environment (such as the first slide presentation or some warming-up on-line meetings that were held before the project actually started) were important in helping the students to cope with future difficulties and team conflicts. We recommend the explicit use of such mechanisms at the beginning of similar projects. An unexpected issue arose because the students in Madrid and Syracuse were not graded homogeneously. This project was a whole independent subject for the students in Madrid, while it just amounted to 30% of the final grade for the students in Syracuse. As a result, we observed a few incidents of conflicts, because a group of students in a team put this assignment over others yet the other group of students didn't want to assign the same level of importance to the assignment. We recommend an explicit grading policy at the beginning. An expanded experience can be designed by including other students. A team may be composed of engineering and business students so that different majors can contribute toward the completion of the ERP project.

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