Evaluating the Influence of PBL on the Development of Soft Skills in a Computer Engineering Undergraduate Program

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***Abstract*—This research full paper investigates the development of soft skills of undergraduate students in a Computer Engineering program that uses problem-based learning (PBL) as its main learning approach. As the role of engineers have changed over the years, their need for a different set of skills has increased. Communication, leadership, creativity and management, known as soft skills, are increasingly needed in their positions. For that reason, undergraduate programs have been pushing to add the development of soft skills in their curriculum. One way to accomplish that change is using active learning approaches. Such approaches usually lead to more student participation in the learning process and, consequently, the development of particular soft skills. This research investigates the use of the active learning approach of Problem-Based Learning (PBL) to enable the development of soft skills of Computer Engineering undergraduate students. Students' skills were assessed through a Likert Scale questionnaire, investigating eight skill categories: Self-Management, Management, Interpersonal skills, Communication, Leadership, Decision Making and Problem Solving, Organization, and Analysis and Creativity. Results show that the students' perceptions of their own skills drop during the course of their studies, but rise when they get closer to their graduation.**

I. Introduction

The role of engineers has changed throughout the years. In the past, engineers had to face large scale problems and solve them, based on a scientific and mathematical approach. Nowadays, they still do. Nonetheless, the role of engineers has been changing towards a more human and socioeconomic approach. Understanding how businesses work and leading employees to succeed and develop themselves has incrementally become a part of engineering jobs [1].

This profile of the modern engineer, in particular for the field of computing, is also guided by standards and choices made by educational institutions. Such guidelines have been leaning towards acquiring skills that are not only technical but also more interdisciplinary and related to socio-economics and entrepreneurship [2], [3].

Regardless of the trends, it is not uncommon for recent graduates to have good overall knowledge of their respective field, but to lack important overall skills such as communication, leadership, creativity, project and time management, among others. These are called soft skills or transferable skills, and are highly favored by industry, specially for new employees, who can more rapidly adjust to the company's environment. Moreover, soft skills are not easy to develop and the process can be long [4].

For the benefits that soft skills bring, developing them during the course of graduation is desirable, and educators have tried to use active learning to achieve this goal. Active learning approaches encourage students to engage in the learning process. By having students playing active roles during their education, it is likely that the experience may help them to grow soft skills.

Problem-Based Learning (PBL) is a well-known active learning approach that offers students the opportunity to learn while solving common problems encountered in their field. The approach tries to replicate problem scenarios that could potentially surface in a workplace environment, but with occasional interference of a tutor, who provides feedback or guidance whenever needed. Students discuss information gathered through research, ideas and possible solutions in brainstorming sessions, where not only they have to find a suitable solution, but also to manage the resources at their hands: time and people (in this case, themselves) [5], [6]. With PBL, it is not rare for students to have to deal with disputes and contrary ideas in their teams, putting them in disagreement situations. All those occurrences may be beneficial to develop both hard and soft skills.

This research aims to understand how a problem-based learning approach can assist the learning of soft skills in an undergraduate program of Computer Engineering. For that purpose, we raised the following research questions to guide this study:

1) Do students' soft skills improve under an active learning approach such as PBL?
2) Which skills are the most developed during an undergraduate program based on the PBL approach?

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3) Which are the most important soft skills, under instructors' views? Do they match the skills most developed by students?

II. Background

In order to answer our research questions, some background is needed. In this section, we explore the concepts of soft skills, PBL and how they are related. After that, related work is discussed.

A. Definition of Soft Skills

Soft skills are "general" abilities that can be applied in a range of contexts, such as effective communication, teamwork skills, problem solving and lifelong learning [7], [8]. However, one technical skill for one type of professional may be considered a soft skill for another. For instance, cultural awareness is an important technical skill for an HR representative, but it is seen as a soft skill for a software engineer. Context plays a big role to determine whether a skill is technical or soft [4].

Schulz divides soft skills into three categories: personal qualities, interpersonal skills and additional skills/knowledge [4]. Shakir divides them into personal attributes, interpersonal skills, and problem solving and decision making abilities [9]. Both perspectives share the concept of competencies towards others (i.e., interpersonal skills) and towards oneself (i.e., intrapersonal skills, personality traits, etc.) as soft skills.

B. Importance of Soft Skills

Soft skills are highly valuable tools in industry. Lack of experience can be compensated by a set of abilities that may help a new employee to adjust and learn how the company works. However, the present reality shows a clear discrepancy between the skills that industry needs and what recent graduates effectively display [10]. These discrepancies include poor communication with customers, poor ability to listen effectively or ask for assistance, lack of writing skills to produce good documentation, and deficiency on problem solving and critical thinking skills. Employers not only value these skills, but also positive attitude and motivation. Graduates lacking these abilities are less likely to accept feedback and learn from mistakes [11].

It is usually important for higher education institutions to help their students develop soft skills during the course of their programs. Guidelines for engineering and computing undergraduate programs have addressed both soft and technical skills as part of the profiles for their graduates [2], [3]. The most frequent soft skills to appear on those guidelines are written and verbal communication, teamwork skills, critical thinking, problem solving and lifelong learning skills.

C. How Soft Skills are Measured

Measuring the level of a soft skill that someone possesses is not an easy task. Because of their nature, soft skills are harder to assess compared to technical skills. Because their outcomes are subtle or develop over longer periods of time, the effects of soft skills are easy to miss.

Kantrowitz developed and validated a method of measuring soft skill performance through self-ratings and supervisor ratings of an individual's performance on different categories of abilities. The categories were created based on interviews with professional experts from various organizations. They were asked to "generate a list of soft skill behaviors required for work in general", rate behaviors "with respect to their representativeness of soft skills performance" and describe incidents of positive and negative behaviors that represent categories of soft skills [12]. Supervisor rating was also used for another study, to compare senior and novice IT professionals [13]. Not only had senior professionals better results, but also faster responses. For their difficulty to assess, soft skills require a personal evaluation or an evaluation from a third person, preferably a supervisor.

D. PBL and Soft Skills

Problem Based Learning (PBL) is an active learning approach that encourages students to solve problems as a means to learn specific concepts [14]. PBL provides an environment where students face problems that try to emulate real life problems. Dealing with these situations allows students to develop skills such as problem solving, interpersonal and team skills, adaptability, self-directed learning, and self-assessment [5].

The PBL learning cycle is also helpful to develop those skills. It is an iterative process that starts with the presentation of a problem and leads to application of new knowledge and abstraction [6]. For the iterative nature of the cycle, students need to address conflicts, stand up for ideas, and communicate and listen effectively. Their active participation in the process requires them to organize their study time and commit to accomplish goals, manage available knowledge resources, practice interpersonal and communication skills to deal with others as well as self-management skills to deal with eventual missteps or lack of motivation. PBL also enforces requirements analysis abilities and creativity to offer possible solutions as well as abilities to make decisions on how to proceed and how to solve the problems encountered. Finally, they develop leadership skills to conduct group discussions or whenever the need for a leader rises.

E. Related Work

Other authors have investigated the theme of soft skills, evaluating students and identifying desirable skills in industry. Walters and Sirotiak, for instance, studied the growth in leadership and communication skills of construction engineering students who went through a PBL course. They discovered a notable increase in the former skill and a moderate increase in the latter [15].

In exploring the needs of industry in terms of desirable skills, one work found that the most common are leadership, communication through multiple levels with both verbal and written skills, adaptability in the face of change, and the ability to plan and negotiate [11], [16].

An attempt to facilitate the development of skills such as communication, teamwork, problem solving, and time management of first year, chemical engineering students was previously reported [17]. According to the authors, these abilities, described in their work as professional skills, had a beneficial environment to be developed through an active learning approach. They also present evidence of the effort to introduce the development of soft skills embedded in the curriculum, rather than in particular courses.

For IT students, a similar effort was issued to address the need for soft skills in their field [18]. Not only the skills were rated as highly important by IT managers, but the author described the challenges in assessing soft skills with students, as they used peer assessment as the tool for data collection.

Motschnig-Pitrik studied the acquisition of soft skills in a Project Management course that uses blended learning as teaching approach [19]. She used participatory action research to uncover that most students felt easier to work in teams and to establish social relationships in the course on project management than in other courses. Later, another work based on the same course provided qualitative students' reactions and the results of quantitative studies on component competencies such as group decision making, adaptability/flexibility, interpersonal relations, and communication [20].

Another study investigated active listening by using written communication in a technology-enhanced course on Soft Skills for Computer Scientists [21]. Their analysis showed that active listening techniques had positive effects on communication, and that instant messaging tools facilitate completely verbalizing one's thoughts before responding.

Idrus investigated how soft skills are integrated in the formal curriculum and in teaching and learning practices on technical courses of a private university in Malaysia [22]. Results suggested that student-centered approaches are more effective to integrate soft skills in technical courses, that instructors place more emphasis on critical thinking and problem solving skills. They also perceived that instructors with industry experience contribute more to the development of students' soft skills.

To facilitate the process of evaluating soft skills, Kantrowitz developed and validated an evaluation tool for those skills. The tool was developed after interviewing several high level engineers active in the industry, to find out their perspectives on the most valuable behaviors. The tool was validated by measuring the skills of college interns, both as self-evaluation and evaluation from their supervisors [12]. We take advantage of this tool and adapt it to the context of PBL-based, undergraduate engineering education.

III. Methodology

This Section describes the research methods used in this work. We describe the scenario, participants, and instruments and procedures for data collection and analysis.

The research employed a quantitative approach to answer the research questions [23].

A. Scenario

This research was conducted at the State University of Feira de Santana (UEFS), located in Feira de Santana, Bahia, Brazil. The institution has offered a Computer Engineering undergraduate program since 2003 [24]. The program uses PBL associated with traditional lectures for computing-related courses. A description of the style and pragmatics of PBL as used in this program is found elsewhere [25], [26]. In terms of curriculum, courses are integrated as a set of theoretical modules and an integrator module (IM), whose purpose is to encourage students to use the knowledge from theoretical modules and gather additional knowledge to solve ill-defined problems [26]. The integrator modules run on tutorial sessions where groups of students meet to discuss the problems along one academic term. The Computer Engineering program has nine different IMs:

- Algorithms
- Programming
- Digital Circuit Design
- Software Engineering
- Concurrency and Connectivity
- Digital System Design
- Electronic Circuit Design
- Digital Signal Processing
- Programming Language Processors

B. Soft Skills under Analysis

For the purpose or this research, eight categories of soft skills were assessed:

- Self-Management (SM)
- Management (M)
- Interpersonal Skills (IP)
- Communication (C)
- Leadership (L)
- Problem Solving and Decision Making (PS)
- Organization (O)
- Analysis and Creativity (AC)

C. Participants

For this study, we invited students taking part in tutorial groups of integrator modules (IMs) to participate in the research. The groups participating in this study were 1) Programming, 2) Software Engineering and 3) Electronic Circuit Design. Those IMs respectively take place on the second, fourth, and sixth semester of the curriculum. The time gap between the IMs was the main reason to choose them. Table I displays the distribution of students in the groups.

Table I
Groups of students participating on the research

Group	Integrator Module	Number of Participants
G1	Programming	23
G2	Software Engineering	22
G3	Electronic Circuit Design	14

The second set of participants were Computer Engineering faculty from our institution who volunteered to contribute

to the research. Only instructors directly involved with the Computer Engineering program and that had previously taught the IMs were asked to participate. A total of 17 faculty participated in this research.

D. Instruments for Data Collection

We asked participating students to answer a survey related to soft skills. Survey questionnaires were adapted from Kantrowitz's instrument [12]. Her survey questionnaire was validated with college students close to graduation that were industry interns at the time. In our study, the population was made of students in different levels of an undergraduate program that uses PBL as the main learning approach. Since both population and environment were different between the studies, we needed to adapt the questionnaire to better represent the environment that students were part of.

The first change was to remove questions that were not relevant to either the PBL approach or the study environment. Two categories of soft skills were removed: Political skills and Selling skills. Political skills refer to network building and company culture awareness, topics not so relevant to classroom environment. Selling skills refer to promoting the company and dealing with customers, both of which aren't needed during the tutorial sessions. The second change was to rephrase the questions from workplace-oriented to classroom-oriented speech (e.g., words like "workplace", "coworkers" and "supervisor" were respectively changed to "tutorial groups", "classmates" and "tutor"). The resulting questionnaire had 96 questions, from the original 106. They were distributed in the categories seen in Table II.

Table II
NUMBER OF QUESTIONS FOR EACH SOFT SKILL CATEGORY

Soft Skill	Number of Questions
Self-Management	21
Management	13
Interpersonal	14
Communication	14
Leadership	8
Problem Solving and Decision Making	13
Organization	6
Analysis and Creativity	5

The questionnaire used a 5-point Likert Scale. The responses categories were, from most negative to most positive: *Fully Disagree*, *Disagree*, *Neither Agree nor Disagree*, *Agree*, and *Fully Agree*. Two attention questions were inserted, to check respondents' focus when answering the survey. For the attention questions, it was required to answer *Completely Disagree*. Any filled questionnaires that failed to correctly mark the attention questions were dismissed.

Since the instrument was an adaptation, researchers from the university that are involved in related topics such as PBL and Computing & Education were asked to evaluate its applicability in this scenario. Their main contribution was the assertion that the questionnaire was broad and complete, but they were unsure of how it would be received by the participants. For that reason, a pilot experiment was performed to validate the instrument as appropriate and the questions as unambiguous. Still, this is the first study in which the instrument is used and stronger validity tests would be valuable.

A second survey was answered by the faculty. The questionnaire consisted of questions regarding their gender, their department, the modules they had previously tutored, and, finally, one question that asked them to rank the nine studied soft skills from most important to least important.

E. Procedures for Data Collection

Student surveys were answered in person. An appointment was scheduled with their tutors by e-mail, explaining the research goal, what would be asked of students and the expected time to fill out the forms. To estimate that time, test subjects were asked to fill them out. Time varied between 15 and 20 minutes. The research was briefly explained to the students and a voluntary informed consent form was signed by the ones who wished to participate. After agreeing to participate, they answered the survey.

A link to the faculty online survey was sent via e-mail, using a group list for the program faculty members. The request was sent twice, some weeks apart, aiming to gather as many responses as possible. We used Google Forms as the online survey tool.

F. Procedures for Data Analysis

Student and faculty survey responses were exported to spreadsheets on Google Sheets. The software was used for initial analysis with descriptive statistics. Later, the data were transferred to SPSS Statistics 17.0 software. The software was used to check data normality by using Shapiro-Wilk test. Then, we used the ANOVA hypothesis test to uncover significant differences between groups and the Tukey post-hoc test to reveal which groups had significant difference between each other. Finally, we drew box plots and error bar diagrams to aid in the visual analysis. The analysis was performed in three different ways: comparison between groups in each soft skill category, comparison between soft skills in each group, and comparison between the ranking of soft skills by the faculty and the actual results from students.

IV. RESULTS

All the categories were tested for normality using Shapiro-Wilk test, where a significance greater than 0.05 represents normal distribution. The ANOVA test with Tukey post-hoc tests were used to check significant differences for each soft skill between groups, with a significance level of 0.05. Results can be seen on Tables III and IV[1].

From the results, we notice that the only one significant difference in the Tukey post-hoc tests was found: on the Interpersonal Skills category, between G1 and G2. That highlights the contrast between the students from these groups, regarding this particular skill. A box plot of the results for Interpersonal Skills category in the three groups can be seen in Figure 1.

[1]ANOVA/Tukey results that show significant differences are highlighted in bold.

Table III
SHAPIRO-WILK TEST RESULTS – P-VALUE

Soft Skill	G1	G2	G3
Self-Management	.063	.440	.572
Management	.106	.418	.450
Interpersonal	.942	.330	.096
Communication	.091	.367	.919
Leadership	.595	.145	.231
Problem Solving and Decision Making	.427	.999	.410
Organization	.144	.874	.303
Analysis and Creativity	.162	.071	.203

Table IV
ANOVA/TUKEY TEST RESULTS – SOFT SKILLS BETWEEN GROUPS – P-VALUE

Soft Skill	G1/G2	G2/G3	G1/G3
Self-Management	.296	.756	.819
Management	.175	.110	.885
Interpersonal	**.003**	.526	.139
Communication	.587	.695	.999
Leadership	.422	.544	.999
Problem Solving and Decision Making	.389	.099	.608
Organization	.410	.119	.644
Analysis and Creativity	.137	.417	.905

Results from G1 show a higher median than both G2 and G3 groups, but G3 had a greater number of outliers, both positive and negative. In fact, this category held the largest number of outliers from all categories, with 9 outliers from the set of 59 participants (15.25%).

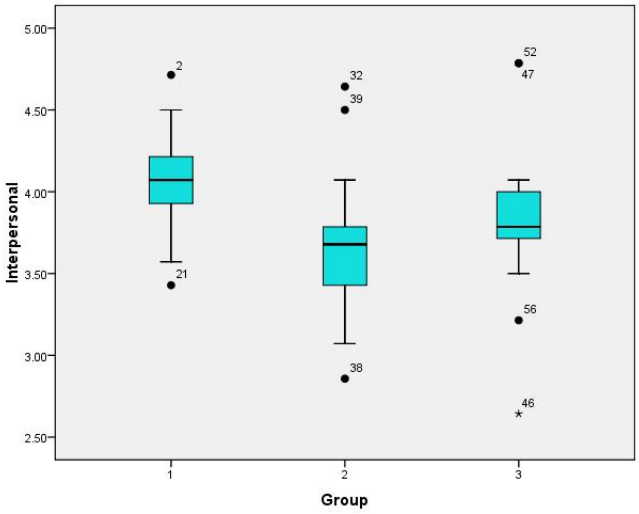

Figure 1. Box-plot for Interpersonal skills

Another category that presented interesting results was Leadership. Even though there wasn't a significant difference in the ANOVA/Tukey results, we perceive from Figure 2 that despite the medians of the groups being close, dispersion between participants decreases as they advance in the program. Furthermore, positive outliers on G3 show individuals who excelled in their leadership perceptions in comparison to their peers.

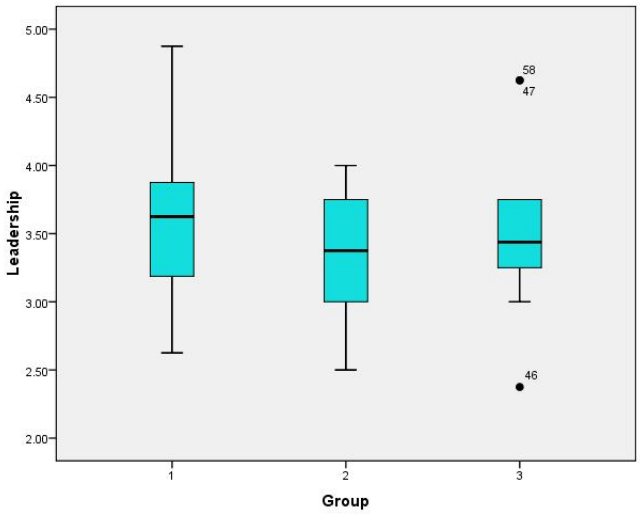

Figure 2. Box-plot for Leadership skills

For completeness, the remaining graphs for this type of analysis are available online for visualization[2].

The second analysis we performed was an intragroup analysis of perception differences between soft skills for each group of participant students, i.e., inside each IM. This analysis helps to identify strengths and weaknesses of each group. We performed ANOVA/Tukey tests on each group to identify significant differences between their skills[3].

Results for Group 1 can be seen on Table V. Significant differences were found between Interpersonal and the other skills, except for Communication and Analysis and Creativity. From Figure 3 we notice that Interpersonal skills are clearly above the other skills. Communication and Analysis and Creativity follow close, on a middle group that did not show significant differences with Interpersonal. The remaining five skills are the weakest of Group 1.

Table V
ANOVA/TUKEY RESULTS FOR GROUP 1 – P-VALUE

Soft Skill	SM	M	IP	C	L	PS	O	AC
SM	-	-	-	-	-	-	-	-
M	.590	-	-	-	-	-	-	-
IP	**.015**	**.000**	-	-	-	-	-	-
C	.983	.108	.189	-	-	-	-	-
L	.943	.997	**.000**	.427	-	-	-	-
PS	.987	.980	**.001**	.607	1	-	-	-
O	.723	1	**.000**	.172	1	.995	-	-
AC	.998	.211	.094	1	.627	.794	.312	-

Results for Group 2 can be seen on Table VI. Significant differences were found between Management and both Interpersonal and Communication. Figure 4 shows that Interper-

[2]Graphs are available at https://sites.google.com/site/fie2018softskills/

[3]Results that show significant differences are highlighted in bold. In the intragroup ANOVA/Tukey tables, SM stands for Self-Management, M for Management, IP for Interpersonal, C for Communication, L for Leadership, PS for Problem Solving and Decision Making, O for Organization, and AC for Analysis and Creativity.

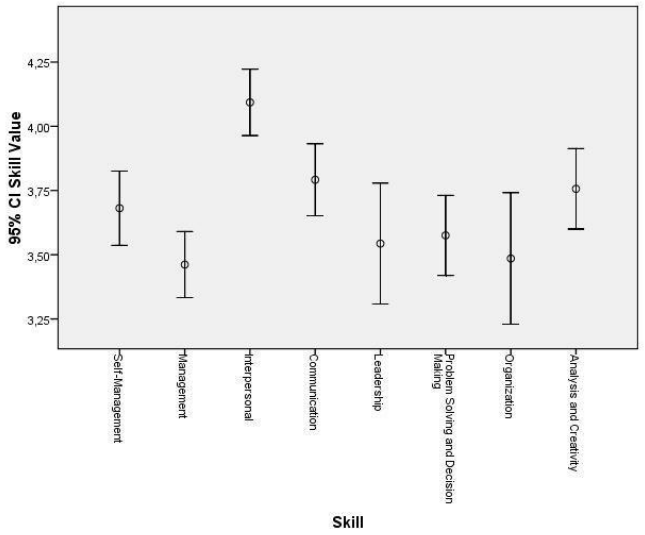

Figure 3. Error Bars for Group 1

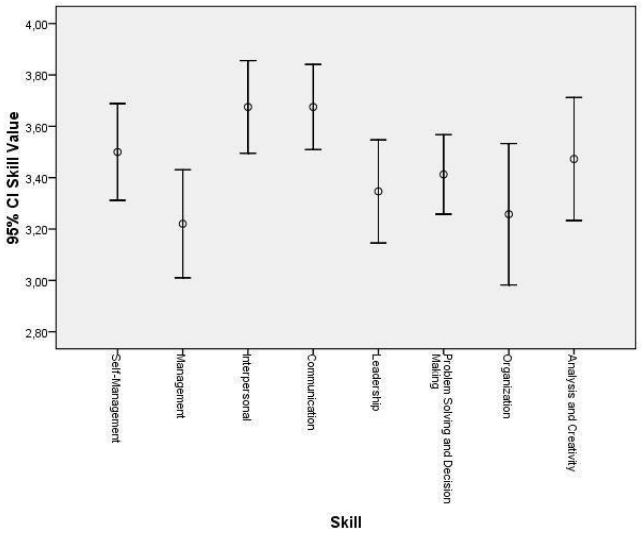

Figure 4. Error Bars for Group 2

sonal and Communication are the two best skills for Group 2. The middle of the pack is composed of Self-Management and Analysis and Creativity. The weakest skills for this group are the remaining four skills.

Table VI
ANOVA/TUKEY RESULTS FOR GROUP 2 – P-VALUE

Soft Skill	SM	M	IP	C	L	PS	O	AC
SM	-	-	-	-	-	-	-	-
M	.483	-	-	-	-	-	-	-
IP	.913	**.029**	-	-	-	-	-	-
C	.913	**.029**	1	-	-	-	-	-
L	.956	.985	.271	.271	-	-	-	-
PS	.998	.866	.565	.565	1	-	-	-
O	.663	1	.062	.062	.998	.954	-	-
AC	1	.615	.832	.832	.985	1	.784	-

The results for Group 3 can be seen on Table VII. There was no significant difference between the skills. We notice from Figure 5 that the skills are very close to each other, with Interpersonal and Communication slightly ahead, and Self-Management, Management and Leadership slightly behind.

Table VII
ANOVA/TUKEY RESULTS FOR GROUP 3 – P-VALUE

Soft Skill	SM	M	IP	C	L	PS	O	AC
SM	-	-	-	-	-	-	-	-
M	1	-	-	-	-	-	-	-
IP	.957	.853	-	-	-	-	-	-
C	.986	.927	1	-	-	-	-	-
L	1	1	.859	.931	-	-	-	-
PS	.999	.990	.999	1	.991	-	-	-
O	1	.998	.994	.999	.998	1	-	-
AC	1	.996	.997	1	.996	1	1	-

The third analysis we performed was a ranking of soft skills from the faculty survey. To give more context, the core of the program is divided into two departments. The Department of Sciences is focused on Computing and Software and the

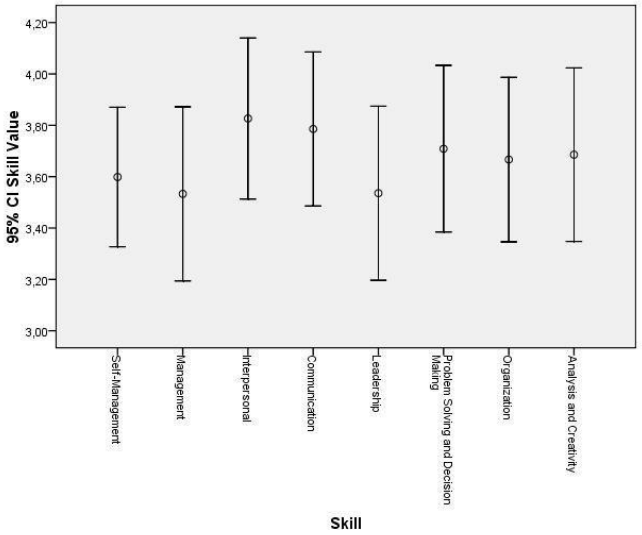

Figure 5. Error Bars for Group 3

Department of Technology is focused on Electronics and Digital Systems. Participants consisted of 11 faculty from the former department and six from the latter. Figure 6 shows the number of participants that had previously tutored each integrator module.

Modules are offered by department, in the following manner:

- Department of Sciences
  - Algorithms
  - Programming
  - Software Engineering
  - Programming Languages Processors
- Department of Technology
  - Project of Digital Circuits
  - Concurrency and Connectivity

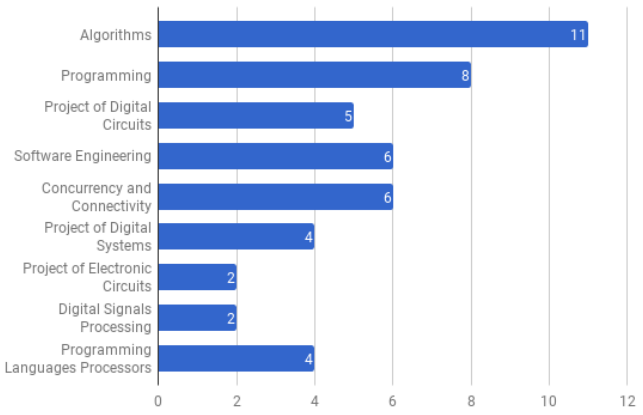

Figure 6. Number of faculty that had tutored each Integrator Module (IM)

- Project of Digital Systems
- Project of Electronic Circuits
- Digital Signals Processing

The participants were asked to rank the soft skills from the most important (rank of 1) to the least important (rank of 8). Later, we normalized the results to have the most important ones with higher scores, which seems more intuitive, as can be seen in Figure 7. It worth noticing that the way we phrased the question forced a relative analysis of importance between skills, and not their absolute level of importance.

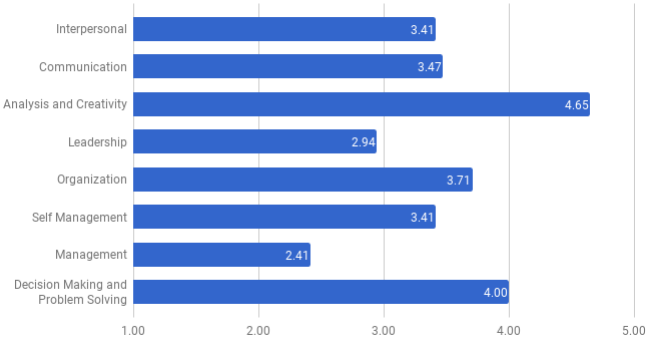

Figure 7. Average ranking of Soft Skills according to their importance as perceived by faculty.

V. Discussion

In this work, we tried to evaluate the influence of PBL on the development of soft skills of undergraduate students of a Computer Engineering program. Here we try to provide answers to our research questions.

The first question was related to the development of soft skills during the program. To answer it, we performed the first analysis, comparing the three groups in the student survey. Since there was no significant difference between Groups 1 and 3 for the investigated soft skills, our first inclination is to assert there was no development of soft skills when comparing a participant in the beginning of the program (Group 1) and one closer to graduation (Group 3). The assumption was that groups more advanced in the program would have more developed skills than less advanced groups, and that was not what we found. What we discovered instead was that, in each investigated category, there was a decrease from Group 1 to Group 2 and an increase from Group 2 to Group 3. With those results, we may assert that there was an evolution from Group 2 to Group 3. However, that came with a notable decrease in the level of the skills from Group 1 to Group 2. That is specially true in the case of Interpersonal skills, since it was the only case of significant difference found.

The second question sought to identify which were the most developed soft skills. It can be answered in two different ways. The first one is to compare Groups 1 and 3 for each skill. However, since Groups 1 and 3 had very close results, the comparison could be better made between Groups 2 and 3. In this way, we identify the largest growth between these groups. The second way is to use the results from Group 3 when comparing skills against each other. This way, we identify the soft skills with the largest absolute results. Using the first approach, Management, Interpersonal, Problem Solving and Decision Making, Organization, and Analysis and Creativity evolved the most. Self-Management, Communication, and Leadership were similar or evolved less. Using the second approach, looking at the results in Figure 5, we notice that Interpersonal and Communication were the best scored skills for senior students. When crossing these two perspectives, we may infer that Interpersonal is definitively the winner, showing good evolution as well as good absolute results.

The third question sought to relate the best ranked soft skills by the faculty with those where students held the best results. Results from Figure 7 put Analysis and Creativity as the most important soft skill, followed by Problem Solving and Decision Making, and then Organization. Management and Leadership were considered the least important. By crossing these results with the results from the previous question, we end up with Problem Solving and Decision Making and Organization as soft skills both viewed as important by faculty and with good self-perceptions by students. Analysis and Creativity, viewed as the most important, was not ahead in absolute values, but presented slight evolution from Group 2 to Group 3.

Results highlight both the skills that are simultaneously less developed and those that are considered the most important. From that intersection, educators interested in the PBL approach and its use to develop soft skills can focus on the skills that are most desirable but aren't being developed as expected (e.g., Communication and Self-Management). On this particular study, it seems that students try to work on developing their skills that had the lowest results, trying to bring them to par with their best skills. This can be noticed by the decrease in the number of significant differences between the skills from Group 1 to Group 3.

One last thing to consider is the likely difference on how the groups perceive themselves, their skills and what is expected of

them. It is possible that students from Group 1 are less rigorous to self-assess their own performance on the skills investigated in this research. Thus, they value their skills as high, in that context. As students advance in the program, the problems they face gradually become more complex, tutorial groups tend to become more heterogeneous (as students might have to take some modules a second time when they fail a course) and both tutors and students might expect more of their performance. Thus, students from Group 2 might be more rigorous in how they assess themselves and their personal expectations. As a consequence, they lower their perceived level of their skills. Students from Group 3 might still hold the same or higher expectation levels, but they compensate that with maturity and experience after over half the required program modules. This hypothesis, however, cannot be proven with this research and further investigation is required.

A. Validity Threats

In this research, participants were asked to answer questions related to their own perceptions of themselves. Also, participants consisted of three distinct groups of students with different experience levels in the program. For that reason, students' self-perceptions could also be different from one group to another. This could possibly skew the data, generating results that misrepresent the differences between groups. However, this research uses more than one way to approach the data. Even with skewed results between groups, the other results that don't rely on that comparison are provided. Additional research, especially with larger samples, could strengthen the results, and we discuss it in our conclusions.

VI. Conclusions

In this work, we sought to better understand the development of soft skills of students of a Computer Engineering undergraduate program that uses the problem-based learning (PBL) as its main learning approach. Both students and faculty were involved in this work by answering surveys. Survey results point to the soft skills regarded as more important, the ones that are better developed at the end of the program and the ones that evolve the most. With those results, strategies can be discussed to address particular strengths of PBL or issues that need improvement.

Although the results were not exactly as we expected, they allowed us to raise new questions to be answered, in an exploratory way. For instance, what causes a skill decrease from Group 1 (freshmen) to Group 2 (sophomores)? Is there a difference in how rigorous the groups assess themselves? How can the approach be improved to help them to further develop their skills? These questions and the motivation to facilitate student growth drive the need for further research. Since we used self-evaluations in this research, future work could use faculty perspective on skill evolution of their students, both in a single course and during the whole program. Another approach is to have students evaluate their peers and compare results to their self-evaluations, aiming to uncover whether those results are comparable. Also, since this research was done comparing students of different levels, a longitudinal study can prove to be more valuable, following the evolution of a group of students as they advance in the program. All those ideas follow from the steps taken in this research, in an attempt to expand the knowledge about soft skills and to help students develop themselves as better professionals and people.

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