Stimulating Research Skills in Undergraduate Computing Students: An Experience Report

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***Abstract*—Research skills are directly related to studying a problem thoroughly, investigating possible solutions, critically analyzing how to solve them, discussing, testing possibilities collaboratively, and adapting or creating new solutions. An undergraduate computing student with these competencies needs to understand and use different research methods, have a business vision, investigate technological alternatives, understand innovation models and their viability and, above all, know how to solve a problem systematically and collaboratively. Considering that these competencies are essentials in computing professionals, the following research question was defined: "*How to stimulate research skills of undergraduate computing students*?". Regarding answering that question, this Research Full Paper describes the design and implementation of an exchange program in the Research Laboratories of a public university in 2018 and 2019, aiming to foster research skills in undergraduate computing students. These experiences showed real benefits regarding students' performance in research, development, and innovation activities, besides improvement points for better management and execution. As the main contribution, it is possible to highlight the proposal for an exchange model between research laboratories, in which undergraduate students in Computing participate in research activities conducted in the PBL modality, learning through complex problems resolution under continuous monitoring and feedback.**

Keywords—Computing Higher Education (CHE), Problem Based Learning, PBL, Computing Skills, Research Skills

I. INTRODUCTION

Information Technology is becoming increasingly influential in companies in all sectors of the economy, in a market where leaders stand out for their high connection power and better customer service. In this scenario, computing professionals need to develop technical skills (hard skills) and non-technical skills (soft skills) to be able to solutions involving the technological and human dimensions required by the market [1]. This is one of the great challenges in Computing Education [2], in addition to the rapid and continuous evolution of its body of knowledge published in [3].

The report Future of Jobs published in the World Economic Forum 2020 [4] highlights future professionals' top three skills: *analytical thinking & innovation*, *active learning & learning strategy*, and *complex problem-solving*. Initiatives such as the Partnership for 21st Century Learning (P21) by Battelle for Kids organization also highlight the 21st Century Competencies, called 4Cs: *Critical Thinking*, *Communication*, *Collaboration*, and *Creativity* [5]. In fact, these skills are directly related to the ability to thoroughly study a problem, investigate possible solutions, critically analyze how to solve them, discuss, test possibilities collaboratively, and thereby adapt or create new solutions. An undergraduate computing student with these competencies needs to understand and use different research methods, have a business vision, investigate technological alternatives, understand innovation models and their viability and, above all, know how to solve a problem systematically and collaboratively.

Scientific research activity is vital for a complete formation of undergraduate students, contributing to the creation of a scientific spirit and reflective thinking, important aspects not only for those who wish to pursue an academic career but also for those who face the professional routine [6] [7] [8]. However, there are some challenges to disseminate the research culture among students [6] [9]. Examples of challenges include an understanding of the research activities themselves (what they are, how to do them) and the requirements for developing them; the apparent difficulty in accessing research laboratories, often subject to a large number of requirements for this; the development of soft skills related to creativity, critical thinking, communication, organization, self-initiation, group work, and persistence; the notion of perspective and continuation of the research work, associating it with a lasting and relevant purpose.

In [9], the study analyzes and compares several educational institutions of excellence, such as Harvard, MIT, Berkeley, Stanford, and others, regarding their ability to propose and manage groups and research projects of great relevance to society. The criteria selected for the evaluation are grouped into two categories: *information for students*, which includes information such as lists of research opportunities, digital libraries, mentors' list, funding opportunities, and research policies; and *promotion of research results*, considering various media such as newsletters, newspapers, events, and study groups. The results show how the institutional organization focused on the research activity and the resources directed to disseminate this activity are essential for its development and consolidation. On the other hand, no criteria related to the student's motivation/interest are presented or discussed, highlighting professional skills and opportunities. In this context, the following research question was defined: *RQ - How to stimulate research skills of undergraduate computing students?*

After an ad hoc investigation on experiences in scientific research by undergraduate students [6] [7] [8] [9], it was possible to understand the importance of experiencing this research activity by students. Thus, the PET group of the Informatics Center at Federal University of Pernambuco (referred here as PET) decided to include in its action plan an activity that could motivate graduate students for research activities. This group is an initiative sponsored by a Tutorial Education Program created by the Brazilian Government to develop quality and academic excellence standards, highlighting the articulation of teaching, research, and extension. The tutor of the PET group is also the leader of the NEXT (*iNnovative Educational eXperience in Technology*) Research Group, which has been working with educational innovations in Computing education for more than 10 years, in particular, in Problem-Based Learning (PBL) research. Thinking about using PBL for scientific research problem-solving experiments, through its digital media communication channel, the group published the following question: "*Imagine if the PET group creates a program, in partnership with research groups and laboratories at this university, to promote an exchange with undergraduate students from this center, allowing them to have contact with research in different areas of Computing. Would you be interested in participating in this program?* ". Of the 91 students who answered the quiz, 91% showed interest in the idea, which led to the structuring of a program involving three research laboratories in Federal University of Pernambuco (UFPE) called PETLab Program (PETLab, for short).

PETLab is an initiative that proposes a period of exchange based on the participation of undergraduate students from the Informatic Center in projects in different research areas during a pre-defined period. The program's objective is to enable students to experience different contexts, problems, and research methods, awakening their interest in this activity and developing the technical and non-technical skills that are so important for their professional training.

This paper reports how the program was created and discusses on the experience of two editions of PETLab, before the COVID-19 pandemic. The results showed real benefits regarding the stimulation of research activity by students and points of improvement for better management and use of the program.

This paper is divided into six sections. After this brief introduction, Section II presents the main theoretical references used to motivate this research and justify its relevance. Section III describes the methods used in this research to create and carry out the PETLab program. Section IV presents the PETLab program in two editions, discussing the main results of these experiences, followed by Section V that presents a brief about the lessons learned. Finally, Section VI comments on the conclusions, limitations of this study, and future works

II. MAIN REFERENCES: SKILLS & STRATEGY

Kivuja [10] highlights the essential skills developed by Trilling and Fadel in their book entitled "*Skills of the 21st century: Learning for life in our times*" [5], as a milestone for changing the pedagogical paradigm. These skills are grouped into four domains: i) the main themes and core skills, such as the 3Rs skills (Reading, wRiting, and aRithmetic) that every educated person must have mastery; ii) Learning and Innovation Skills (LIS), which require skills such as critical thinking and problem-solving; iii) Career and life skills, requiring skills such as collaboration, teamwork and leadership and; iv) Digital literacy skills, which requires skills such as computer literacy and digital fluency.

With respect to item iv, although computers and digital technologies play a central role in the development and use of skills, Kivunja [11] emphasizes "*the more essential skills for 21st century learning and occupations relate not just to the application of technology but more importantly, to the ability to engage in independent critical thinking, and a high level of problem solving, often using technology*.".

In this current study, the concept of "Research skills" concerning the item ii (LIS).

A. Stimulating Research Skills

Regarding learning and innovation skills, Trilling and Fadel [5] highlight how it is possible to stimulate critical thinking in students through inductive and deductive reasoning through critical analysis, interpretation, reflection, and evaluation. In this context, it is necessary to foster in our students the ability to solve problems that they will encounter in the workplace of the 21st century after the academic environment, focusing not only on the knowledge of the pedagogical content but on the process of applying this content in life situations to solve problems, taking the students to real experiences [10].

Studies in [7] and [8] show that the participation of undergraduate students in experiences involving research for problem-solving can improve the skills of research through understanding its processes, improving communication and critical thinking [8]. In this context, the authors emphasize that these experiences contribute to greater clarity of the student's career, stimulating them for postgraduate education and awakening the student's desire for scientific research as a career opportunity [7].

Some studies reinforce the potential of research experiences in stimulating technical and non-technical skills [12] [13] [14] [15]. Omolola et al. highlight some technical skills such as data entry, analysis, interpretation, and various laboratory skills and techniques [12]. From the point of view of soft skills, studies also report the positive impact of research experiences on students' perception of their self-efficacy, contributing to their self-confidence and professional socialization when feeling a member of the scientific community. The study in [13] also emphasize the value of inquiry, modeling, and metacognition skills, highlighting that if students learn the processes of scientific investigation and modeling and being able to monitor and reflect on their process on an ongoing basis, they can engage more in research and get better performance. This last point reinforces the importance of monitoring learning and reflecting on it, both by the students' guiding teachers and by the students themselves.

B. Problem-Based Learning as Educational Strategy

The Problem-Based Learning (PBL) is a constructivist model of teaching and learning centered on the student, where learning starts from a critical reflection on a problem [16] [17]. According to [18], PBL is based on the principle of knowledge construction using real-life problems to learning of theories, skills, and attitudes. Its creators justify its application to respond to the teachers' perception that students were completing their courses with many concepts but little capacity to use them and integrate them into real experiences [19].

PBL was born in medical education [17]. However, in the last two decades, it started to be adopted by courses in other areas of knowledge, often experimentally or in isolated courses, proving to apply to teaching in different branches of knowledge such as Computing and Engineering [20]. According to [20], the use of the PBL approach in the teaching of Computing contributes to the development of professionals with a holistic view, critical thinking, and capable of dealing with the different situations that the market presents, essential competencies in the training of a researcher.

In [21], the authors defined a framework to apply PBL in teaching Computing. This framework aims to facilitate the management of teaching processes in the PBL approach through techniques and management models. Intended for the pedagogical team, this instrument indicates a set of actions that need to be considered at each step of the Plan-Do-Check-Act cycle of Deming, relating the actors' roles and responsibilities for effective application of the PBL approach. The current study implemented a simplified version of this framework. Regarding the "Do" step, this study is based on a classic process defined in [22] that recommends a four-step problem-solving process:

1) Define the predicted problem before starting to work on it.

2) Draw a plan for the solution of the conceptualized problem.

3) Solve the problem, putting the designed plan into action.

4) Reflect on the problem, which involves an analysis of how the problem-solving was good, from the perspective of those involved with the problem and the solution.

Section 4 discusses the adoption of these processes in the case studies context.

III. Research Method

This paper reports experiences, therefore, it presents a work that was done in real life and with a practical goal. To conduct these experiences, we used a mix of methods, with emphasis on qualitative research and descriptive approach. According to Patton in [23], research is said to be qualitative when it aims to investigate what people do, know, think, and feel through data collection techniques such as observation, interviews, questionnaires, document analysis, among others. Thus, this study was conducted in four steps:

i. *Understanding the problem* – ad hoc literature review on the developing of research competencies in graduation students, discussion of the studies found, and formulation of a quiz for students of computer graduation.

ii. *Conception of solution* – analysis of the problem and quiz results; ideation and definition of an exchange program in research laboratories; and validation of the solution with laboratories' researchers.

iii. *Implementation and management of the solution* – implementation of the program and management of its activities.

iv. *Reflection and lessons learned* – assessment of results and lessons learned; realization of improvements in the program; elaboration of experience report.

Results of step (i) are commented in Sections I and II of this paper. The following subsections will detail the methods used in steps (ii) and (iii). Step iv will be discussed in Sections IV and V.

A. Program Conception

For the conception of the research program, a Design Thinking (DT) process was used [24]. The basic principle of Design Research is that the knowledge, understanding, and resolution of a problem is acquired in the construction and application of an artifact in the context of a specific problem. Four steps define the process of creating a solution in this approach, as shown in Fig. 1.

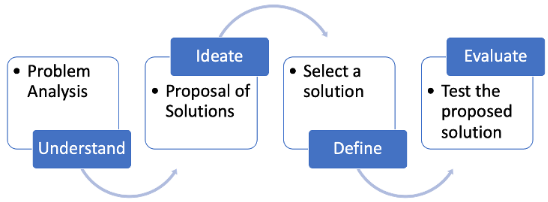

Fig. 1. DT applied in program conception

Based on the understanding of the challenges of computer education and the demands for training professionals with technical and non-technical skills, the PBL approach has been used in the context of the educational initiatives of the PET group, for example, in the training of programmers in the Python language, with very positive results [25]. However, it has also made evident some deficiencies, particularly concerning research activity, which involves research, analyzing problems, and proposing effective solutions. To investigate the motivation of students with this activity, according to the research question in Section 1, a quiz was conducted with undergraduate students in computing within Centro de Informática at UFPE. From the answers, it was possible to identify the interest of these students in trying diverse research activities in different laboratories within a short period of time, but sufficient to understand how can be carried out the research activity in each of them.

The idea of the program involved about 5 students of the PET group (here, called *PBL tutors*), the group tutor (*Senior tutor*), and professors/researchers representing the research laboratories (referenced by Labs) in the second semester of 2017. Initially, the PBL tutors invited four research laboratories, and all were willing to collaborate with the program, proposing problems, coordinating activities, and providing the necessary physical and technological infrastructure. At this stage, it was identified that a minimum period to try out the laboratory's activities would be 1 month. In addition, when considering the capacity of the laboratories, the reception of up to 4 students at a time would be manageable.

The definition step established new requirements and conditions. The program would be conducted in partnership with 3 research laboratories. Each laboratory would receive 4 students at a time, therefore, totalling the offer of 12 places. The program made calls to fill vacancies via a public notice for all students at the Computing center. The PBL tutors would be responsible for the selection process and monitoring the activities of the groups in each laboratory. The monitoring of the PBL tutors with the students of the program would be carried out weekly. The assessment process would involve the multidirectional evaluations, as shown in Fig. 2: PBL tutors to student, laboratory to student, students to students (including self-assessment, also called 360 evaluation), and student to laboratory.

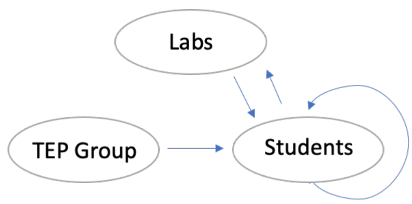

Fig. 2. Assessment flows in the Program

Each group of students would experience each laboratory for 1 month. The program would have a duration of 3.5 months, considering the initial week for student guidance and the final week to close and present activities in the three laboratories.

The proposal was validated in a meeting with a representative from each of the three participating laboratories, the senior tutor, and two PBL tutors through a presentation of the program planning. After everyone's approval, three recommendations were made at this time: that the notice would restrict the call to students over the fourth semester (most of the Center's courses are 10 semesters in duration); students should have some experience in software programming; the responsibility for defining activities and allocating students would rest with each laboratory.

B. *Program Management*

For the program's management, we used the Deming's PDCA cycle – Plan, Do, Check, and Act [26], as shown in Fig. 3.

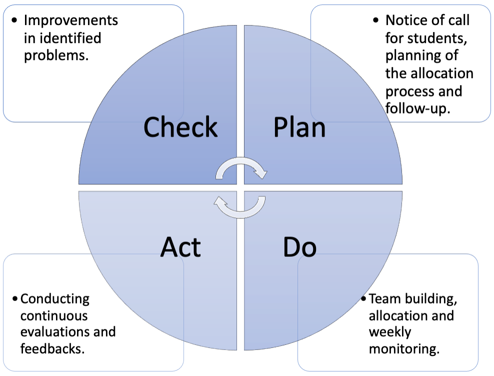

Fig. 3. Management steps based on PDCA cycle

The Plan stage included the preparation of the student selection notice, the definition of the selection process, the definition of the assessment process, and artifacts provided for the program's control.

The Do stage involved selecting students for the program, the definition of teams, the definition of the sequence of allocation of teams in the laboratories, the control of the agenda and schedules of the participants in the laboratories, and the holding of weekly follow-ups meetings. Concerning research activities, each laboratory had its activity planning, following the four-stage PBL process (define the predicted problem, draw a plan for the solution, solve the problem, and reflect on the problem), as mentioned in Section 2.2. Also, the students signed a confidentiality agreement on the activities developed.

The Check and Act stages were based on an assessment process composed of flows in Fig. 2. Table I shows the objective, criteria, type of skill, and frequency for each flow.

In the PBL tutors to student flow, feedback collected in the weekly follow-up meetings allowed to report problems and conflicts between students to the laboratories, monitor Lab satisfaction regarding students' participation, and solve problems along with the program (Act stage).

These results were recorded in a spreadsheet, consolidated using the arithmetic average of the five criteria in Table 1. Other aspects directly linked to the research skills of students are assessed in the flows Labs to the student and students to students (including, self-evaluation). These evaluations are carried out through electronic forms, asynchronously. Finally, students assess the research labs at the end of each experiment concerning support and contribution to research skills.

TABLE I. TABLE TYPE STYLES

PBL Tutors to Student	
Objective	Monitoring the student activities, solving process and collaboration between students.
Skills	Hard skills (coordination, management) and Soft skills
Criteria	Planned activities, performed activities, project methodology, strong points, and improvement points
Frequency	Weekly
Labs to Student	
Objective	Monitoring research activities/project and teamwork.
Skills	Hard skills (problem understanding, solution analyses) and Soft skills
Criteria	Problem understanding, quality of solutions, self-initiative, commitment, communication, collaboration, and innovation/creativity
Frequency	Biweekly
Students to Students, Self-evaluation	
Objective	Assess research skills from students' perspectives
Skills	Soft skills
Criteria	commitment, communication, collaboration, self-initiative, creativity, and level of learning
Frequency	Biweekly
Student to Labs	
Objective	Evaluate Lab's support, availability, and contribution to research skills
Skills	*No apply*
Criteria	Infrastructure, market alignment, innovation, laboratory management, contribution to learning
Frequency	At the end of the research project/ activities of each Lab.

Based on this assessment process, it was also possible to identify improvement points in the first edition, which was considered input to the program's second edition.

C. *Research Limitations*

Considering the qualitative characteristic of this research, we highlight three main limitations: the collection and reporting of data, which are often subjective; the sample size; and the lack of more studies with the same research purposes.

As for the first item, several data collection instruments were used in the student assessment process, including student diaries, PBL tutors' assessment sheets, Labs assessment forms, and self-assessment forms. We chose to use criteria based on the Likert scale to generate consolidated reports, but always supported by subjective opinion. However, to present the results in this paper, we decided to use graphs consolidated with the averages of these evaluations and only a few personal statements from PBL tutors, providing an overview of the monitoring carried out throughout the experience with focus on research skills.

As for the sample size, although the program offered 12 places, only five students passed the selection process in the first edition of the program, of which only four concluded. In the second edition, the program managed to fill all 12 spots. To present the detailed results, we chose to use the sample from the first edition, allowing better visualization of the evaluation process and applied criteria without overloading graphics and tables.

Finally, it is important to emphasize the difficulty in finding studies focused on the development of competencies, in particular the research competence, with practical experience in computing education. This lack made a comparative analysis between proposals with the same objective difficult, although the few experiences found were of high quality.

IV. EXPERIENCES REPORT

The PETLab Program was run in two editions and involved three research laboratories from the UFPE University:

- *Lab1* – this Lab works in several lines of research related to health and has the mission "To train quality human resources and develop methods, systems and products biotechnologies associated with human and animal diagnosis and therapeutic methods, aiming at the best quality of life for everyone."
- *Lab2* – this Lab investigates and develops tools, techniques, and processes to increase software productivity levels without compromising software quality and developers' life factors.
- *Lab3* – this Lab carries out Research, Development, and Innovation projects in three major areas, which are visualization, tracking, and natural interaction, all converging to a large technological field that is augmented reality. These projects are carried out in collaboration with academic and research institutions, government agencies, and partners in the industrial sector in Brazil and abroad.

Each of the laboratories defined their research planning for the program, with at least one coordinating researcher in direct contact with the undergraduate students participating in the program.

The first edition of the program allowed the practical experience PETLab Program implementation and important points of improvement. As it involves a small group of participants, we will be detailing the results in the different aspects planned and just highlighting the differences in the second edition.

A. First Edition: Plan & Do

A call published on the Computing center website launched the program, initially offering twelve vacancies. To participate in the selection process, the candidate should be a student in one of the computing courses (Computer Science – CC, Computer Engineering – EC, or Information Systems – SI), attending from the fourth semester of a course of 10 semesters. Thirteen students registered in the program, of which 5 students were selected based on a rigorous selection process, based on curriculum evaluation, group dynamics, and interviews. Of the students who passed the selection process, two were from the CC course, two from the IS course and one student from the EC course. One of the SI students dropped out of the course in the first month due to lack of time. Thus, 4 students completed the program fully, all male and aged between 19-21 years, divided in two groups (S1 and S2; S3 and S4).

The duration of the program was three and a half months, considering one month of experience in each of the three research laboratories, with a total workload of 240 hours, 80 hours for each laboratory.

Initially, the students were organized into two groups: the first, with two students; the second, with three students. The groups started their activities allocated, first, in Lab3 and Lab2, leaving Lab1 for the next round.

Each laboratory proposed problems according to their research projects, requiring students to understand these problems, plan tasks to solve them, and present a solution in different types of artifacts (process, data analysis, software applications, etc.). These activities allowed performing steps 1 and 2 of the PBL process in Section 2.2. Thus, Lab 1 proposed challenges in biotechnology, Lab 2 presented demands for improvements in software development, and Lab 3 proposed innovation projects with virtual reality, involving ideation and prototyping from components developed in-house.

The continuous monitoring of the students by PBL tutors and the assessment process in several aspects allowed the implementation of steps 3 and 4 of the PBL process. During the three-month period, the two groups were involved in activities planned and managed by the three partner research laboratories (Lab1, Lab2, and Lab3), monitored weekly by PBL tutors through follow-up meetings (status report). At each status report, the criteria described in Table 1 were assessed: planned activities, performed activities, project methodology, stronger and improvement points.

Based on the follow-up results, the PBL tutors acted as the program's coordinator, identifying problems, and monitoring the well-being of those involved, being an interlocutor with partner laboratories. In addition, every 15 days, the laboratories also evaluated the students' work and the students also evaluated themselves, according to criteria in Table 1. Finally, students evaluated the laboratories subjectively at the end of each experiment, highlighting the program's support and availability.

This assessment process made it possible to identify strengths and weaknesses throughout the program, allowing monitoring of learning and metacognition, in addition to program management, based on continuous improvements.

B. First Edition: Check & Act

Four students completed the program fully, all with a good performance, positively evaluated by the partner laboratories, PBL tutors, and themselves. The following value scale was used in all evaluations: *1 - Insufficient; 2 - Regular; 3 - Good; 4 - Very good; 5 - Excellent*.

Fig. 4 shows the averages of the results collected in the Labs and self-assessments. Looking at Figure 4, we see a very positive performance, highlighting improvements in self-initiative and communication skills. Another point to highlight is a self-evaluation that is sometimes more critical than the Lab evaluation (student S2, per example), showing the student's awareness of the self-regulation process. We also highlight the level of learning from "very good" to "excellent" from the students' perspective.

Stu	EF	PU	QS	SI	CM	CL	CC	CR	L
S1	L-to-S	4,6	4,6	5	5	4,8	4,8	4,5	
	Self-E			4,8	5	4,5	4,5	4,5	4,5
S2	L-to-S	4,6	4,8	4,8	4,8	4,8	4,6	4,5	
	Self-E			3	3,6	4,3	3,5	3,6	4,6
S3	L-to-S	4,6	4,5	4,5	4,8	4,8	4,6	4,5	
	Self-E			4,5	4,6	5	4,6	4,6	4,6
S4	L-to-S	4,1	4,3	3,8	4,3	4,5	3,6	4,1	
	Self-E			3,8	4,1	3,3	5	4	4,6
Legends:									
Stu - student; EF - Evaluation Flow; PU - Problem Understanding;									
QS - Quality Solution; SI - Self-Initiative; CM - Commitment;									
CL - Collaboration; CC - Communication; CR - Criativity									
L - How much did I learning?									

Fig. 4. Lab to student and self-evaluation results

Fig. 5 shows the results of the monitoring of project activities by the PBL tutors, under the aspects of planning, management, and coordination of activities (as shown in Table 1). Over the 11 weeks of projects, we see teams performing very well in the aspects obtained throughout the program, between very good and excellent. We can still see a low performance in week seven in the figure due to the absence of the laboratory researcher. This event highlighted the importance of reinforcing the Labs' commitment to the program, anticipating risks of this type.

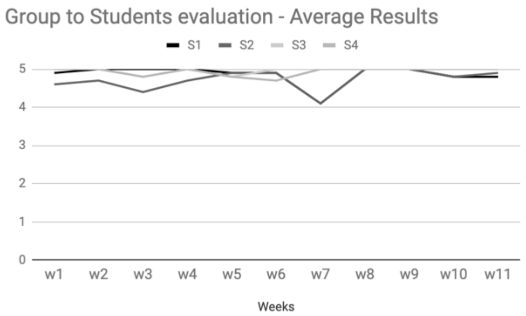

Fig. 5. Lab to student and self-evaluation results

Fig. 6 presents a general summary of the students' averages, considering the evaluation flows PBL tutors to students, Labs to students, and Self-evaluation. In the graph in Figure 6, it is possible to see a high performance of the participating students, between very good and excellent in the three perspectives.

From the first meetings, the motivation, engagement, and commitment of the students, as well as those of the partner laboratories, proved to be quite high, even in the face of difficulties, as can be seen in the feedbacks from PBL tutors:

"*Their tasks were well planned. They were able to learn well from the challenges and achieved an exciting result. Integration between the team looked very good. And the people at the Lab3 were very supportive*".

"*They chose the article and made the installation and execution of the necessary software to carry out the tests. They had problems with the project's dependencies and the operating system. In the end, they managed to overcome the difficulties and carry out the project. Using Slack, drive, git, and ROS (Robot Operating System - Computer Vision Tool) for communication between members and project execution. They are very excited about the project*".

"*The students seemed very interested in the project's theme and brought some contributions that will help the researchers of the Lab2 in the development of their scientific articles. The activities were developed satisfactorily, and the two students at the Lab2 managed to work very well in a group. It was exciting to see that they are working on something that will really contribute to projects developed in the laboratory today. It shows the impact of the project*".

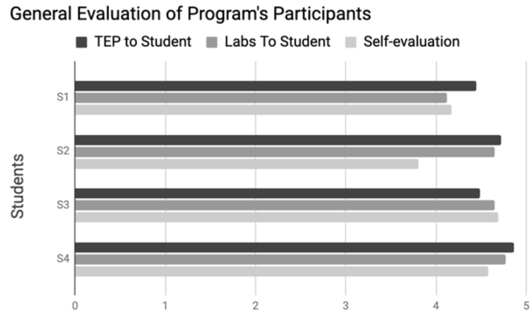

Fig. 6. General results of the first edition

From the final feedback from students, it was possible to extract the positive side of working in different laboratory environments, in areas such as Biology, Virtual and Augmented Reality, and Software Engineering, with praise for the mentoring of the projects developed, seen as interesting and a fully of learning.

C. Second Edition: Plan & Do

Before the second edition of the program was held, a lesson learned meeting was held with the three participating laboratories, generating some recommendations for the program. The program extended the target audience, considering that students taking the 3rd period of the course would develop the competencies necessary to carry out research projects. Also, a one-week interval between the activities of each laboratory was inserted in the program schedule of the second edition, preventing the final deliveries in the same period of the evaluations in the undergraduate courses, when the students would have little time available for extracurricular activities.

Again, the program was launched by a notice published through the communication media of the Computing center, offering a total of 12 vacancies, with the same prerequisites of the first program, except for the participation of students attending the third semester of computing courses. The program duration was 14 weeks, considering a month of experience in each of the three research laboratories and a week of the interval between each of these rounds. The workload was maintained: 240 total hours, 80 hours for each lab.

In this edition, 28 students signed up for the selection process, mostly attending the 3rd or 4th semester of their undergraduate course. After analyzing curricula and interviews, the PET group selected 12 of them. Based on the availability of the students, they were divided into three groups of 4 members. Each group was initially allocated to a laboratory by lot such that a group would experience all laboratories by the end of the program. During the 14-week period, the groups perform activities planned and managed by the three partner research laboratories (Lab1, Lab2, and Lab3), again monitored weekly by the PBL tutors, through status meetings, and under the same evaluation criteria as the first edition.

In addition to the status report at the end of the project iteration, the laboratories evaluated the student's results, the students self-assessed themselves concerning their performance, and, finally, the students also assessed the laboratories based on the experience obtained, according to the same criteria in the first edition. This time, the evaluations allowed the students to improve and let the laboratories themselves adapt research methodologies from each iteration based on their evaluation feedback.

D. Second Edition: Check & Act

All students completed the program with good performance, considering the evaluations of the laboratories, the PBL tutors, and self-evaluation. Fig. 7 shows a high performance of the most of students, between very good and excellent in the three perspectives. Again, the following value scale was used in all evaluations: *1 - Insufficient; 2 - Regular; 3 - Good; 4 - Very good; 5 - Excellent*.

The students signalizing some improvement points in their laboratories as the low availability of responsible mentors to monitor the development of the students within the laboratory and the low degree of complexity of the proposed challenge. These points are highlighted in some of the reports made by the participants themselves:

"*I thought we could have had a better follow-up and had been taught something specific to the laboratory, as we were left with a project that only involved technologies that we were already minimally familiar with.*"

"*I think the ideal situation is to allocate teams to research not much in the initial phase because it makes it difficult (technical) support that the mentor can provide for the pair*."

"*The impression is that the laboratory was not properly programmed to receive the group and pass on a more challenging project. Most of the learning was gained by reading scientific texts during the first week, making the practical part more of a "mechanical work" than research and logical reasoning*."

Although this situation is related to the minority of the program's projects, the feedback from these students points to the importance of monitoring mentors during the stages of research development and a more rigorous selection of projects that groups of students will work on.

In the second edition of the program, most of the challenges were solved, and found new ones. Among the new challenges, the following stand out:

- The permanent difficulty in allocating members of the PET group as PBL tutors in the weekly monitoring of the activities of students. This group carried out others time-consuming activities.
- The decrease in the attendance of some students in the status report meeting as the schedule progresses.
- The proposal of projects outside the appropriate scope for the objectives of the program.

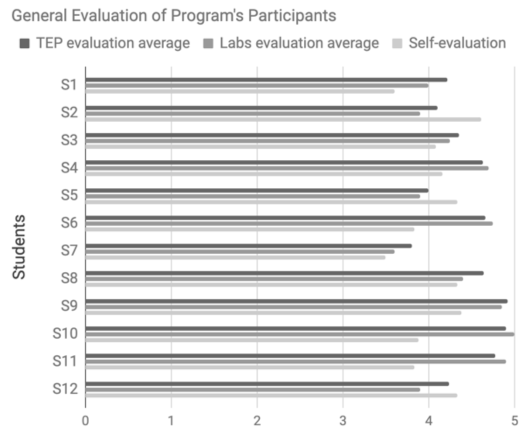

Fig. 7. General results of the second edition

Despite the challenges, the experiences brought a first contact with the research area for many participants and enabled the development of technical and behavioral skills during the process.

Still, new talents were acquired by the laboratories in varying degrees of engagement. After completing the program, some participants continued to be involved voluntarily in the respective research project until its completeness. Other participants entered the laboratories in a more lasting way, through public notices and research grants in their respective activities.

Because of the COVID-19 pandemic scenario, the PET group canceled the 2020 edition. Even so, the laboratories reported their interest in participating in a possible third edition

V. General Discussions

The multidisciplinary characteristic of the research laboratories involved in the program allowed the participating students to know and experience several research areas in Computing, promoting hard and soft skills. The integration of knowledge in different research fields has helped better learn new technical knowledge, from comparing and realizing parallels with other subjects that have some similarities and generating new ideas that involve more than one form of thinking. These experiences contributed to developing skills associated with creativity, innovation, and critical thinking, strongly related to research skills. Also, learning different fields based on teamwork increases the limits of our language, which is essential for the broader learning process and the development of soft skills, such as communication and collaboration.

From the point of view of technical knowledge, the various projects proposed by the laboratories challenged the teams of students to work with new technologies, many of them relevant not only in research. In this way, even the participants who did not desire to continue in the research area after that first experience obtained the knowledge and the practice of tools that they will be able to use in their future activities. This process of discovering and using tools contributes to awakening students to the possibility of building their own and innovative solutions to problems pertinent to Computing, even though they are still in the initial periods of their courses.

The interest of the laboratories and the PET group in yet another edition of the program reinforces the importance of feedback for improvements and adjustments seeking even better experiences. The PETLab program involves the pillars of research and teaching. It is an important activity within the objectives of the PET group in favor of improving the experience of undergraduate courses, considering the learning and impact on all participants. In addition, this program allows you to act directly on the problem related to the central research question by planting a seed to encourage scientific research in students of undergraduate courses in Computing

VI. Conclusions

From a central research question "*How to stimulate research skills of undergraduate computing students?*", this study describes the design and implementation of an exchange program in the research laboratories of a public university in 2018 and 2019, conducted by a group of undergraduate students (pet.cin.ufpe.br) together with NEXT research group (next.cin.ufpe.br), to foster research skills in undergraduate computing students. The NEXT Research Group has been working with educational innovations in Computing education for more than ten years. In its experiences, the adoption of more radical active methodologies such as Problem-Based Learning (PBL) and its essence "learning by doing" has shown very positive results in developing personal skills such as teamwork, communication, self-initiative, critical thinking, holistic vision, and collaboration. On the other hand, from the evaluations in PBL experiences, it was possible to see that many students have difficulty with appropriation and use of methods, resisting research activities that require much reading, interpretation, critical analysis, reflection, and evaluation. Regarding these challenges, it is important to emphasize that the process of mastering research and investigation methods is unlikely to be successful without real experiences. The more students have research experiences, the more research skills they have. In this context, the PETLab program tried to supply this need with authentic experiences in research laboratories in different areas of knowledge and generate opportunities to experiment with varying research methods, keeping the essence "learning by doing" of PBL. Finally, the assessment process and continuous monitoring of students, with feedback from the various actors involved, including self-evaluation, allowed them to develop an awareness of the relevance of the research work, stimulating several students to continue these activities after the program conclusion.

As the following steps, new editions of PETLab are planned, with different partner laboratories, even allowing students who have already experienced the experience to repeat it. For this, we hope that the pandemic challenges are controlled, considering that most experiments in research laboratories need to be in loco.

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