A Learning Framework for Career Transition Towards Software Engineering

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***Abstract*—This Research-to-Practice paper details the first edition of a one-year graduate course aimed at facilitating professionals' transition to R&D careers. The proposed methodology successfully addressed the typical challenges inherent in such transitions, aggravated by the specificity of the geographic location of the course. This course is the result of an industry-academy partnership, seeking to attract STEM professionals who intend to migrate to the R&D career in the informatics and computer technology sector. The curriculum, based on the Multiple vortices of Know-How (a methodology of interconnected learning activities) has eleven subjects distributed in three sections (leveling, advanced and residency). The first class had twenty-five students with granted scholarships and five volunteers. The paper details the course methodology and its activities, providing a highlight of how to apply the framework, including the research projects and the residency. Moreover, the paper discusses the student performance, and the course evaluation from the students' perspective. Furthermore, the paper discusses the lessons learned and adjustments implemented for the second class, including the cultivation of soft skills and methods for conducting individual evaluations. Finally, the evidence shows that the methodology is reproducible and viable across a diverse range of scenarios.**

***Index Terms*—Career choice, Higher Education, Professional development, Professional skills, STEM**

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I. Introduction

Brazil has implemented various programs aimed at promoting the economical development of the Amazon region. One of those, the Informatics Law [1] states that companies of the informatics and telecommunication sectors have to invest up to 5% of its gross revenue on research and development (R&D) to benefit from a set of tax incentives. Exploring an economy centered around the software industry holds great appeal for Amazon. However, the success of this policy depends on overcoming structuring challenges, such as poor educational system, geographical isolation, hot and humid weather, and inadequate basic services. Furthermore, the companies dispute the scare professionals with local competitors, start-ups in the emerging technology ecosystem, and (given the new trend of remote jobs) companies all over the world. Therefore, the key critical success factor for this R&D policy is the development of human resources.

Several programs emerged to leverage the qualification gap between the recently graduated informatics students and the R&D demand. The present work took a different course of action, by attracting professionals from other areas, such as mathematics, statistics, earth sciences and engineering. The obvious consequence of such approach is a considerable higher qualification gap. This where the software residency appears as an interesting methodology. By immersing the participant in real projects, a residency has the potential to work in the professional profile as a whole and in a shorter time.

One can identify various initiatives that have employed the software residency approach [2] [3] [4] [5] [6]

[7], however, none has explicitly shown an intention to encourage a shift toward informatics from other careers. Furthermore, while these initiatives were valuable in their respective contexts, we were unable to replicate them in our region. Not only because they were implemented in a more favorable context, but they did not translate their experiences into a systematic and reproducible methodology.

The contribution of this paper is two-folded: We have developed a comprehensive year-long qualification program for individuals who intend to seize the opportunity to enter the R&D segment, while providing a systematic and reproducible methodology. The key focus lies in our methodology, a dynamic framework crafted around interconnected and engaging activities. We presented the results attained thus far, and shared few valuable lessons learned from the inaugural class.

This paper is organized as follows. Section II summarizes the theoretical background similar initiatives. Section III presents the methodology, while Section IV details its realization. Section V discusses the main results, and VI presents the changes due to the lessons learned during Class of 2023. VII concludes the paper.

II. Fundamentals and Related Works

In [8], the author introduced the Student Involvement Theory for the development of the student in a more complete sense. The methodology is based on five assumptions concerning student engagemente:

1) It comes with physical and psychological involvement in various learning objects;
2) Engagement stimulus must be continuous;
3) It has qualitative and quantitative aspects;
4) The greater it is, the greater is the learning;
5) The effectiveness of any learning approach depends on its ability to promote engagement.

In [9], the author highlights that when dealing with students who lack essential fundamentals, a successful approach goes beyond just encouraging engagement. It should also embrace positive expectations, regular assessment and feedback, and various forms of personal support and reinforcement. While these principles may seem straightforward, their effective integration demands ongoing planning and execution efforts. Success in one cycle doesn't automatically ensure the same positive outcome in the next. The overall performance of a class hinges on a range of interconnected factors, such as the prevailing leadership, student backgrounds, and the organizational and environmental context during that specific course cycle. It's crucial to recognize that educators are also susceptible to the demotivating factors that can impact their students.

TABLE I
The Four Vortices and Attributes

Vortex	Cycle	Nº cycl	Public	Skill	Depth	Conn
1	6 m.	2	in	hard	deep	<3-,>2
2	6 m.	1	in	both	moderate	<1,>3,>4
3	3 d.	1	off	hard	superf.	<e,>1+
4	4 m.	1	in	both	deep	<2, >3

A. *The Learning Vortices Framework*

In [10], the authors proposed a framework that interconnects engaging learning activities (learning vortices). This connection is established considering factors like the duration of the cycle, the complexity of the learning object, the desired hard and soft skills, and the number of students involved. A *Learning Vortex* is an involvement activity with a self-contained subject, connected to another Vortex in such a way to contribute either in depth of knowledge or in number of persons to the whole Program [10, page 2].

The framework defines each vortex by its attributes: time period of a cycle, cycles per year, target public (in: for university students; off: for anyone), skills (hard, soft, both), depth of teaching (superficial, moderate or deep). Connection is the attribute that distinguishes any given involving activity as a vortex. The output of an activity i may be connected as the input of activity j in the same class term ($> j$) or may receive the output from it ($< j$). The activity i may receive an input from an activity of the previous term ($< j-$) or may produce an output to the next ($> j+$). The connection $< e$ means that potentially anyone can participate in the activity.

- Vortex 1. Courses: A curriculum related to the target profile: software development for mobile devices;
- Vortex 2. Talent Development Program: A Scholarship program with granting criteria;
- Vortex 3. Short Period Events: To mark important milestones, such as curse start and conclusion;
- Vortex 4. Advanced qualification: Focused on students with distinctive performance.

Table I summarizes the vortices. Vortex 1 primary input comes from the graduation workshop (a vortex 3) of the previous class. The connection implies that the announcement of the next class is part of the graduation workshop of the previous class. Similarly, participants of Vortex 1 will be eligible to participate in the talent development program (Vortex 2), in which the best students goes to Vortex 4. The short-term events receive input from all other vortices, and it is intended to provide candidates interested in the next class, closing the cycle. Figure 1 illustrates the four vortices interaction. The vortex framework was first implemented in a previous qualification program. The results were extensively documented in [11], [12], [13] and [14].

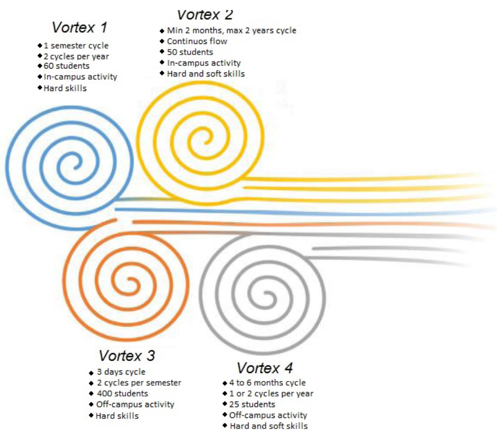

Fig. 1. Interconnected vortices. Source: [10]

B. Software Residency

The residency program was established by William Osler and his colleagues at Johns Hopkins University with the objective of refining medical training, later extending to other health-related courses. While in the health field, residency is a necessary condition for students to gain practical experience, while minimizing the risk to patients, in other areas, internships and supervised projects may also fulfill this role, although without the same focus and dedication. In other words, software residency aims to expedite student learning, and a more fitting term would be 'immersion.' However, we will maintain the residency term to avoid an unproductive discussion on semantics.

The Center for Informatics at the Federal University of Pernambuco (CIn) introduced what is likely the oldest software residency program in Brazil [2]. With support from the private sector, CIn's software engineering residency program has been in existence for over 20 years, with a specific focus on test engineering. However, unlike the proposal outlined in this article, the CIn program was not designed to facilitate career transitions. Furthermore, the CIn program does not place a significant emphasis on research activities.

Google in Residency (GIR) [6] established a residency in 2006 with the aim of creating an intersection between Science and Art. It is an initiative that aims to promote diversity in the Technology industry, in collaboration with HBCUs (Historically Black Colleges and Universities) and HSIs (Hispanic Serving Institutions).

CESAR is a R&D center located at the Porto Digital, in the city of Recife, Brazil. They developed a Software Residency program [3], aiming to integrate the selected students into companies partnering with the program. By this initiative, CESAR asseverates they promote the exchange of values and the assimilation of organizational culture among participants.

The Serrana Region Technology Park, located in the state of Rio de Janeiro, maintains a Residency program aimed at young people aged 16 and over [5]. In 2021, the program selected 183 students residing in municipalities in the region. Lasting 4.5 months, the program aims to promote qualification in technology to meet the specific demands of the region.

More recently, the University of Mackenzie, in the city of São Paulo, started to offer an one year long software residency for their undergraduate students [7] enrolled in one of their informatics courses. The program is for undergraduate students, and is complementary to the conventional studies.

A careful analysis of these initiatives reveals that their primary concern is in a set of hard skills of those already in the informatics career path. This is the reason for the high correlation between the level of student background and the complexity of the learning content. In our case, the desired participants do not have a strong background, and gap between existing knowledge and the course objectives is larger than usual. Moreover, the learning content we aim to provide is much more complex than any of those initiatives (machine learning and evolutionary algorithms applied to test automation).

The present initiative is the result of a public university and the private sector partnership. Called IARTES: ***I****nteligência* ***Ar****tificial para Engenharia de* ***Te****ste de* ***S****oftware*, in Portuguese (directly translated to Artificial Intelligence for Software Testing Engineering). It is an one year software residency course based on the Vortex framework. We defined four vortices to keep the students in a continuum of positive perspective towards the conclusion, despite the complexity of the subjects.

Table II summarizes the comparison among the above mentioned initiatives and IARTES based on the following attributes.

- Host: The host educational institution: Public (pub)

TABLE II
COMPARING PREVIOUS SOFTWARE RESIDENCY INITIATIVES

Name	Host	Spr	Srt	Dur	Pbc	Pur	Cnt
CIn	pub	Moto	2005	12	ihe	qlf	adv
GIR	ngo	Google	2006	ver	ahe	soc	bgn
Cesar	pub	none	200x	ver	ihe	qlf	cmd
Serratec	go	none	200x	4.5	hs	qlf	beg
Mackenzie	prv	none	2021	ver	ihe	qlf	cmd
IARTES	pub	Moto	2022	12	ahe	trs	gp

or private (prv) college, non-governmental organization (ngo), governmental organization (go), other;

- Sponsor (Spr): The funding organization;
- Start (Srt): First edition year;
- Duration (Drn): Course duration in months;
- Public (Pbc): Senior students or alumnus of informatics higher educational institution(ihe), senior students or alumnus of high-school (hs), professionals holding a higher-education degree (ahe), professionals with no higher education (nhs);
- Purpose (Pur): To better qualify the participant with good background (qlf); a social initiative for vulnerable groups (soc); to promote the career transition of the participants (trs);
- Content (Cnt) refers to the complexity of the desired hard skills. For beginners (beg), commodity hard-skills that are part of a typical major program in informatics (cmd). Advanced hard-skills that are not usually taught on a major program (adv); hard-skills usually part of a graduate program (gp).

III. COURSE METHODOLOGY

As we mentioned before, we found no organized method to create a software residency. Given that the Vortices framework provides the needed tools to define the engaging activities, the student evaluation methods and the evaluation assessment methods, we adapted it to the residency approach.

A. *Course Objectives: The Hard and Soft Skills*

Main course objective: After graduation, the course the participant should be able to plan, create, execute and evaluate machine learning based automatic tests.

Hard skils include:

- Project management and agile software development process, with emphasis on test life cycle management;
- Test automation and test automation framework;
- Java and Phyton Android development tool-chain;
- Machine learning frameworks (Keras and TensorFlow).

With the aim of promoting a career transition, the objective of the IARTES course defines also the needed soft skills, which are: Autonomy, writing and oral skills, team work, resilience, and analytical thinking.

B. *Tailoring The Vortices Framework*

The first step to apply the vortices framework is to define the engaging activity (vortex) to address each of the desired hard and soft skills, then carefully connect the activities. IARTES has the following four vortices:

Vortex 1: Leveling module Created to address the gap in the need background, Vortex 1 has four subjects: (1) Programming Contextualized to Testing; (2) Introduction to Project Planning; (3) Programming of Android Applications; (4) Software Development Process with SCRUM.

Vortex 1 has the following attributes:

- Cycle: 12 weeks (3 weeks per subject);
- Number of Cycles: 1 Cycle per IARTES class;
- Public: in-campus (for IARTES students only);
- Skills: hard-skills, including software programming, development process, project management;
- Depth: moderate. The students learn what is necessary to acquire autonomy in the selected subjects;
- Connection: Vortex 1 is connected to vortex 2 of the previous class and vortex 3.

Vortex 2: Short Period Events As in the original proposal [10], this activity has the objective to highlight an important milestone, and to bridge two or more vortices. We prepared two events for IARTES:

- Qualification Workshop, when the students will have their research projects evaluated by a board of specialists. Although the event is open to the public, we do not make a relevant promotion effort. The expectations is to join the university community, along with attendees from third partner institutions. This event has as input the students from the Advanced Courses (Vortex 3) and send them to the Research Program activity (Vortex 4), while serving to promote IARTES to those that are closer;
- Graduation Workshop. A public and heavily advertised workshop. The students present the results of their work and will be evaluated by the same board of their respective qualification. The conclusion workshop has keynote speakers, and a panel formed by industry representatives. This event has as input the students from the Research Program (Vortex 4), and closes the cycle with Vortex 1 of the next class.

Vortex 2 has the following attributes:

- Cycle: 2 days per event;
- Number of Cycles: 2 events per IARTES class;
- Public: off-campus;
- Skills: hard-skills and soft skills (writing skills, presentation skills, etc);
- Depth: superficial. During the short period event it is not possible to go deep into a subject;
- Connection: Vortex 2 connects 3 to 4, and 4 to vortex 1 of the next class.

Vortex 3. Advanced Qualification Module A set of seven subjects to provide the necessary qualification for the research program (vortex 4). They are: 1. Test, Verification & Validation; 2. Software testing automation; 3. Introduction to Artificial Intelligence, with focus on machine learning; 4. Deep Neural Network, with focus on application frameworks (Keras, TensonFlow, etc.); 5. Applied Machine Learning, with focus on Natural Language Processing; 6. Evolutionary Algorithms applied to software testing; 7. Search based software testing.

Vortex 3 has the following attributes:

- Cycle: 21 weeks (3 weeks per subject);
- Number of Cycles: 1 cycle per IARTES class;
- Public: in-campus (for IARTES students only);
- Skills: hard-skills, advanced programming, including machine learning, test automation;
- Depth: Deep. The students are challenged to get the most of each subject;
- Connection: Vortex 3 connects to 1, 2, and 4.

Vortex 4: Research Program This is the activity that defines the residency model. We divided the students into squads with of 3 to 4 members and assigned a research project to each one. This vortex is divided into two phases:

- **Qualification** when the team will work to define and plan their research. The result of this phase is the project proposals, that will be evaluated in terms of relevance and feasibility during one of the short period events (vortex 2). This phase is also connected with vortex 1 as input. The squads work on the qualification while doing the vortex 3, which means these two vortices overlap;
- **Graduation** The squads will immerse 100% in the research project execution. This is the residency, when they will receive no more formal lectures, just advising from a senior researched allocated specifically for this purpose. The squads will receive a final evaluation with respect to their research outcomes. This vortex is connected with vortex 3 as input and vortex 2 as output.

TABLE III
THE FOUR IARTES VORTICES

Vortex	Cycle	N^{o} cyc	Public	Skill	Depth	Conn
1	12 w.	1	in	hard	moderate	<2-,>3
2	2 d.	2	off	hard	superf.	<3,>4,>1+
3	21 w.	1	in	both	deep	<1,>2,>4
4	21 w.	1	in	both	deep	<2,<3, >2

The research themes assigned to the squads includes image based test automation, generative adversarial networks (GAN), deep reinforcement learning, huge test case data base management, and robotics.

Vortex 4 has the following attributes:

- Cycle: 10 weeks;
- Number of Cycles: 1 cycle per IARTES class;
- Public: in-campus (for IARTES students only);
- Skills: hard-skills, selected topics from each specific research theme;
- Depth: Deep. The students are challenged to publish their results;
- Connection: Vortex 4 is connected to 2 and 3.

IV. FIRST CLASS IMPLEMENTATION DETAILS

The selection of the participants considered the course purpose of promoting career transition. The target candidate should be a STEM course alumni that is struggling to land one of the several opened positions in the local R&D ecosystem. During the interviews the selection board avoids candidates interested on having just yet another good certificate.

The enrollment package includes a scholarship compatible to a salary of a junior professional, a notebook for personal use, a high-end smartphone for experiments, and a seat in the software development workplace specially prepared for the course.Also, the students would have exclusive access to four high-performance computers (Intel i7 13o generation, 128MB RAM, 1 TB HDD, NVIDIA RTX 3070TI), besides the university computing servers, cluster and Internet infrastructure.

A. *First Class Participant Profile*

We selected 25 candidates out of the 92 applicants. The main characteristics of those selected candidates are:

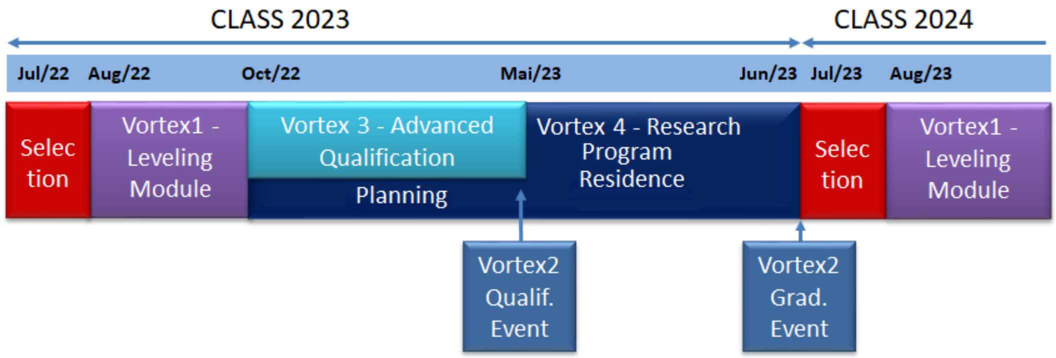

Fig. 2. The 4 IARTES vortices connections throughout Class of 2023 and the transition to the Class of 2024 class.

- 15 male, 10 females, 4 unemployed, 5 earning around 4K USD/year, 7 earning around 6K USD/year, 9 earning around 12K USD/year[1];
- None are graduated from the hosting college, 4 are bachelors from the hosting university's engineering school, 6 graduated from a public state university, the remaining have a degree from one of the low ranked local private colleges;
- 8 are electrical engineers, 2 automation/industrial engineers, 2 mechanical/mechatronics engineers, 1 is a lawyer, 3 has a degree different than bachelor[2], and the remaining have bachelor degree on one of the accredited majors in informatics.

It is important to note that we are paying scholarships to motivate the students to persevere and, as a corollary, to hold them accountable for their performance.

B. The Control Groups

We had two control groups. The first one was formed by 5 applicants with previous software testing automation experience. This control group helped to qualify the student performance. The hypothesis is that a successful course will make previous knowledge about the main theme less relevant.

The second one was composed by five extra participants without scholarships, selected among the applicants who are also employees of one of the sponsors. After being informed that due to conflicting reasons they were not eligible to a scholarship, five of them accepted to enroll anyway. This control group helped us to get a better view about the role of the scholarship on the student persistence. Therefore, the size of the first class is 30 students, 25 with and 5 without scholarship. Two participants were part of both groups.

C. Remarks on the Faculty Profile

We had 9 professors assigned to the 11 subjects, including a member of the Brazilian Academy of Science, the coordinator of the graduation program, the coordinator of the software engineering major, a distinctive professor[3] in the area of embedded systems. The quality of the faculty member helped to set the students' performance expectation.

D. Vortices Dynamics

The expected dedication is 25 to 30 hours per week. As the subjects occupy 10 in-class hours per week, the students have an weekly workload of around 15 to 20 hours. During the residency (second part of Vortex 4) the students are expected to spend a full time in the projects. Although the students can work at home, we encourage them to come to the campus. The maximum grade a student can earn is 10, being the minimum approval grade 7. If an student fails two or more subjects, he is not eligible to graduate.

The first class of IARTES (Class of 2023) started on August 2022 and finished on the first week of July, 2023. Figure 2 shows the dynamics of the four vortices during the course timeline, including the transition to the Class of 2024.

V. Results

This paper focuses on the findings and lessons learned about Class of 2023.

[1]The salary expectations for a junior R&D position in Manaus is somewhere between 15k USD/year to 20k USD/year

[2]Brazil has others higher education degrees, different from the Bachelor. There is the *licenciatura*, aiming to prepare teachers, and *tecnólogo*, a higher education course that lasts one year less that a bachelor.

[3]As distinctive, we mean a professor who receives scholarship by the Brazilian Graduation Agency as a recognition of his productivity.

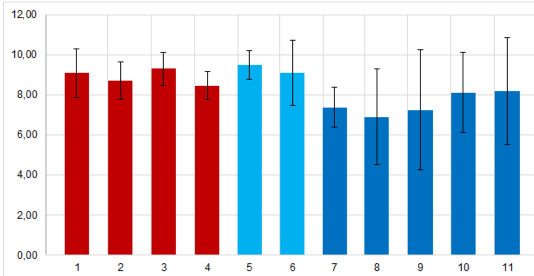

Fig. 3. The average performance of the students on all 11 subjects.

A. *Student Performance*

Two students failed Class of 2023. They may recover the failed disciplines in the class of 2024. The average grade of Class of 2023 was 8.36 (of 10); 8.89 for the Leveling Module, and 8.06 for the Advanced Module.

In the top 25% (8 best students), 3 were part of control group 1 (1st, 2nd and 4th), showing the influence of having previous experience in test engineering. However, their average grade (9.27) was only 4.39% higher that the other 5 top 25% (8.88). Considering the whole class, the average grade of students from control group 1 was 8.65, 4.30% above the class average out of group 1 (8.30), a very similar value. In our perception, this is an evidence that the course successfully brought all the participants to a competitive level of knowledge. Concerning control group 2 (5 students without scholarship), the best ranked student was in the 11th position. The average grade of the students in group 2 was 7.93, 6.61% bellow the students from group 2 (8.45). This is evidence of the importance of scholarships to avoid dropout. We also noted that the best ranked control group 2 student was also part of control group 1; the lowest ranked among the 28 approved students was also part of both groups, and the two failed students where part of no control groups.

Figure 3 shows average and standard deviations of all 11 subjects. One may note that the dispersion increases with the subject complexity (see Section III). The subjects in dark green are all related to artificial intelligence (machine learning and evolutionary algorithms).

Concerning the research programs, seven of the eight squads had their projects qualified and successfully presented in the graduation event. Four of them presented their results in important Brazilian conferences on software and system engineering , and there is a fifth one under construction. It is important to note that, in Brazil, a specialization course like IARTES is not expected to produce academics papers. These four publications are evidences that the provided qualification was effective, for they could produce verifiable results.

The engagement during the subjects was beyond expectations. We had no drop out, and even the two students that failed requested to redo the subjects. Fortunately, the university office of the vice provost for research and graduate studies granted their request, and both are now part of class of 2024. Another evidence of a high level of engagement is that all students without scholarships successfully concluded the course. Their hours spent in the campus, however, was bellow expectations. Most of them preferred to work from home.

B. *The Course Survey Response*

It is also important to evaluate the course from the students' point of view. The Vortices frameworks provides a tool for that in the form of a survey. The goal of the survey is to assess the course value as perceived by the students. We adapted the survey created to evaluate a previous qualification program , which has the following characteristics:

- It follows the principles of [15]–[17];
- It has only short yes-no questions that are scrambled when the survey is opened;
- It uses the Ideal Participant Reference (IPR), which is the preferable answers from the point of view of the faculty. The students answers are compared with the IPR. For each equal answer the student scores one point (IPR Score). As higher is the IPR score, as closer is the survey response to the IPR.
- The Relevance Perception index, the Maturity index and Confidence Index, as defined in [13];
- It also has 1 pair of redundant and 4 pair of anti-redundant questions[4], to mitigate the impact of personal bias and distracted answers. They are also used to measure the Confidence index.

The IARTES survey has 39 yes/no questions distributed into two sections:

- Maturity Section: 19 questions about the student view of his qualification before starting the course, changes in his career plan and expectations about the future;
- Relevance Perception Section: 20 questions about student's perceived relevance, strengths, and weaknesses of the course. W added questions about student's knowledge of course purpose and objectives.

[4]Two questions are anti-redundant if their answers lead to the same conclusion when one is ”yes” and the other is ”no” [13]. An example of anti-redundancy is *Q1: Would you participate in the program as a volunteer? Q2: After you finished, the only thing really worthy was the scholarship?*

TABLE IV
GENERAL FIGURES OF THE SURVEY RESPONSES. NUMBER OF RESPONDENTS: 25 OUT OF 30. AVERAGE CONFIDENCE: 87.08%. STANDARD DEVIATION: 7.35.

Index	Mean (%)	Std Dev	Corr.
Maturity	80.84	6.96	0.33
Relevance	76.40	10.25	0.37
IPR Score	78.56	6.28	0.47

The Maturity section addresses the participant's profile. Relevance perception section aims to asses how the student perceived the course importance for his career. Please, refer to [13] for a detailed description of how to design, apply and analyse the survey.

C. Assessing the Survey Responses

The survey indexes are computed as follows:

- **Maturity index** is the average of the student IPR score relative to the 19 Maturity questions;
- **Relevance Perception Index** is the average of the student IPR score relative to the 20 Relevance Perception questions;
- **IPR** Score is the average of the student IPR score with respect the whole survey;
- **Confidence index** is computed based on contradicting redundant and anti-redundant questions. If the students misses all those questions his survey will be considered unreliable (50% of confidence). Considering that the survey has five pairs of these questions, each contradiction will decrease the respondent confidence by 10%.

We also computed the standard deviations of the indexes. Table IV summarizes the answers of 25 (out of 30) students. Given that the response was volunteered, we considered a very representative result.

As pointed out in [13], the IPR score has the objective to encapsulate faculty's bias and subjectiveness. The Maturity index indicates the students answered 80.84% of the questions as the *Ideal Participant*. A 100% index would mean the student's response is totally aligned to the faculty's preferable profile. Similarly, the perceived relevance of the course was 76.40% of what the faculty believed how a totally satisfied student would answer.

The correlation value indicates that there is a loose, although always positive, trend relating the computed indexes and the confidence index. This trend can be used to modulate the overall relevance perception, increasing or decreasing it based on the signal and intensity of the correlation. In the present case, we should increase.

VI. LESSONS LEARNED

After the graduation of Class of 2023 we made a series of lessons learning meeting to prepare for 2024. The most important lessons, and the resulting changes were:

- The students were shifting away from the attitude of autonomy and self-motivation regarding the research projects, as their focus became more centered on the course subjects. By the time they realized their project was a requirement to graduate the course, there were only 8 weeks left until the qualification event. To work on this issue, we anticipated the input connection of the event (Vortex 2) from the output of Vortex 3 to Vortex 1;
- Another aspect was the amount of hours spent on campus. Despite all the technology resources to allow the remote interaction of the squad members, we are convinced that for the proposal of career shift, the workplace is the preferred environment to boost their qualification. We will reinforce to the Class of 2024 the in-campus work by providing a tool to reward the students based on the hours the spent in the campus. Our objective is to double the number of squads with accepted papers;
- The Evolutionary Algorithm subject had around 70% of his content covered by the Search Based Test subject. By removing that subject we increased the number the weeks of the residency from 8 to 12;
- We realized that evaluating the squad as a whole was a mistake, as the students who performed very well were covering their under-performing colleagues. For Class of 2024, the advisors have to break down the research project into well defined workpackages, assign them to each squad member, and evaluate accordingly. On one hand, the squad members evaluation will be individualized by their respective workpackage deliverable, and, on the other hand, we will be able to maintain the collective accountability by the overall project deliverable;
- As for the selection process, we will keep the first control group (candidates with previous experience), but we will not open extra vacancies for volunteers (control group 2). We believe that the importance of scholarships is well established and the overload caused by the 20% class increase is not worthy anymore.

The open issue is the course capacity. We do not have the resources to increase the number of students per class, without compromising the course objectives. A feasible strategy would be to promote IARTES to others universities in the region. The northern Brazilian states of Acre, Roraima, Rondônia and Amapá are also struggling to create their own R&D ecosystem.

VII. Conclusion

This paper presented a detailed report about the creation, realization and evaluation of the first class of IARTES, a one year course aiming to help professionals with a graduate diploma to transition to the software engineering career. The course is the result of the partnership between the largest public university of Amazonas and the private sector, in the context of the so called Brazilian Informatics Law.

IARTES applied the *Vortices Framework*, with four connected learning activities, including a corpora of leveling and advanced subjects, short-duration events and a research program. Each activity has its attributes. The course lasts eleven months, focusing on enable the students to apply machine learning to test automation.

The control groups helped to better understand the methodology. Control group 2 evidenced that the scholarship plays a fundamental role in the student's perseverance. The methodology provided a evaluation survey and quantitative indexes to assess the results. Those indexes are fundamental to compare the performance of a class with respect to the previous ones. Moreover, the IPR is a interesting way to concentrate the desired answer.

The lessons learned include the necessity to change the learning activities sequence to promote the continuous engagement. Moreover, we had to redesign the project evaluation process to assess both individual and collective performance. As for the assessment of hard-skills performance, we are satisfied with the results. However, we still need to improve the assessment of soft-skill, an important aspect for a career transition to the R%D profile. We expect that the partnership with the psychologist area will provide a more complete tool to follow the students progress. The most relevant open issue is the course scale, as 25 students per year (considering no dropouts) are not enough to provide the needed human resource for our R%D ecosystem. We will address this issue during the upcoming classes.

Finally, the authors believe this learning program is sufficiently documented to allow its replication in others scenarios. Of special interest would be those with structuring problems, as we have in the Amazon region.

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