Enhancement Program for Macro Capabilities: Empowering Engineering Students at Sapienza University of Rome through Experimental Training

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Abstract. This paper presents studies on an evolution in guidance and educational models, in order to assist individuals in making informed university choices and charting clear paths for career satisfaction and development.
The current job market is undergoing continuous transformation, becoming increasingly competitive. Consequently, employees face ever-increasing responsibilities and the need to adapt to new roles, which may differ from their previous career paths. Our research, initially introduced at ICL 2023, continues today defining new learning tools to track and monitor the development of well-defined sets of Macro Capabilities associated to professional categories. Furthermore, we would like to find out whether it is possible to identify predispositions for certain roles through stimuli on various work contexts and aptitudes, and if professional profiles solely defined by Macro Capabilities could prepare young people to consciously face the world of work. Our training experimentation targeted high school students and engineering students. The aim was to enhance the participants' ability to present themselves on the market by acting on their skill sets and constantly monitoring growth indicators. The goal was to empower students to construct their own skill set for navigating their career path utilizing the educational tools of the COACH_ING model like laboratories and group work. The analysis of the results demonstrates how the training Train to Career method, utilizing the tools of the COACH_ING model, based on appropriate coaching methodologies, aids new generations of engineers in crafting careers that resonate with their attitudes. Additionally, the results indicated a growing speed of thought among the new generations, alongside a heightened orientation towards critical thinking, facilitating optimal reshaping and reorienting of choices. Assessment processes and analysis of results enable the new generations of engineers to boost their motivation, expand their horizons, and embrace new and continuous learning opportunities.

Keywords: Engineering students, Assessment, Educational model.

1 Context

The current job market is experiencing constant change and growing competitiveness. As a result, employees are facing increasing responsibilities and the need to adapt to new roles, often without sufficient support [1]. These roles may significantly differ from their previous career paths. What is required in such a dynamic and often disorienting [1] workplace is the ability to quickly adapt while maintaining awareness of one's technical and human value. Therefore, possessing the necessary skills to thrive in this environment is crucial [2]. Changing roles can be draining and may instil fear of inadequacy. It often leads to a sense of not being fully aligned with new responsibilities, affecting both individuals and work groups who may lack clear information about their members' new tasks [3]. In response to these challenges, there is a need for an evolution in guidance and educational models. Our work, initially introduced at ICL 2023, began by identifying Macro Capabilities (MCs) specific to various roles and functions, and continues today defining new learning tools to track and monitor the development of these MCs [4]. The evolution of our work has led to the construction of new classroom processes, through the use of the COACH_ING model (integration between the skills of traditional coaching [5,6] with the programmatic and systems engineering ones [7] resulting in a set of 16 skills called the COACH_ING skills or C_I for short). New tools have been integrated and innovative laboratories have been defined for different targets [8].

Following what was proposed at ICL23, we interviewed the students who took part in the previous workshops [9] and submitted them a questionnaire with which to reconstruct and recognize the MCs linked to their professional role [10]. The results highlighted a "non-awareness" of the role held rather than of one's MCs.

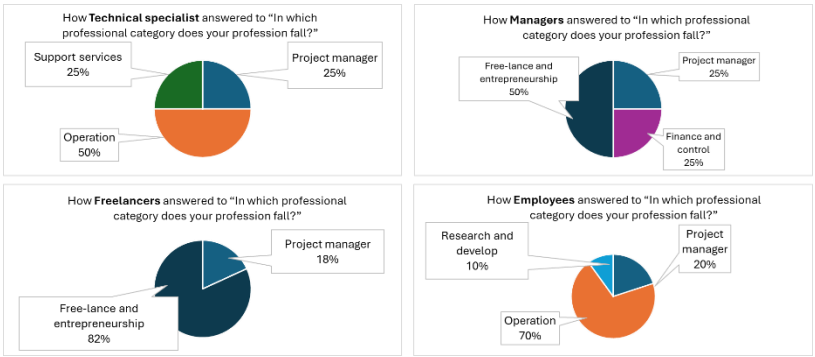

Fig. 1. Knowledge of their role by professionals.

The evidence of these results led us to propose, in the classroom, methodologies that would develop awareness of the duties linked to the role and, above all, of the MCs connected to them. For further verification, we wanted to propose the same classroom process to a group of secondary school students. In summary, the objective is to propose our model as a method of "REORIENTATION IN PROGRESS" (a sort of "route recalculation" of road navigators) and to equip our students with TOOLS to know how

to navigate a evolving market and gain confidence with a package of useful MCs. This work is organized into 3 sections: in the first section, the purpose of the work and the methodological approach in the classroom are introduced; in the second, the new experiments with school students and, in the third, proposals for a new future of integrated engineering education are shown, based on what has been observed.

2 Purpose

Our study on new engineering educational models, along with the relevant data gathering and analysis, continued with experimentation of applying assessment [11] tools for the next generation of engineers. This experimentation took place at the Sapienza Faculty of Engineering and in private engineering companies. Since in most cases engineers choose their professional path based on their specialization, the interventions were focused on transferring strategies, linked to the COACH_ING model, used to overcome "technical" barriers, seen as cognitive biases. We want to lead students to consider, in addition to technical skills, also strategic ones, to reach a goal that is in line with their aspirations and a better quality of life. To create a system capable of freeing personal aspirations from any constraints, we have once again re-engineered the process, enriching it with assessments that can stimulate the development and measurability of MCs linked to professional categories. To understand in detail the process followed in each intervention it is essential to transfer the basic elements that compose it and which are transferred to the students in the first meeting. The first element is the premise, in which the entire path connected to each single step performed is explained (Fig.2) and the related intervention techniques.

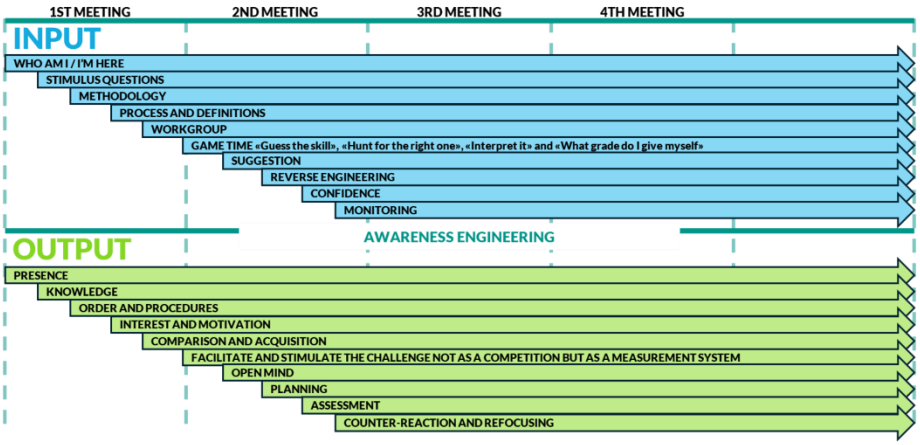

Fig. 2. Techniques used during the entire classroom sessions

The second is the sharing of the methodology adopted in each individual intervention, so that the change process is enhanced, and performance is not nourished in the participants but, rather, curiosity is stimulated, see Fig. 3.

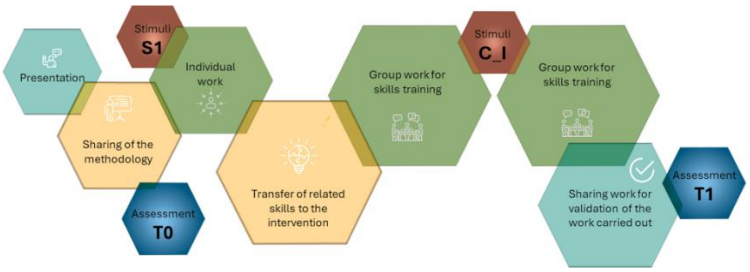

Fig. 3. Classroom process

In this regard, in Fig. 4 is reported the result of a typical group work that is the expression, not only, of what built by students but above all of an organized work that has determined the development, in individuals, of specific skills, self-evaluable and measurable.

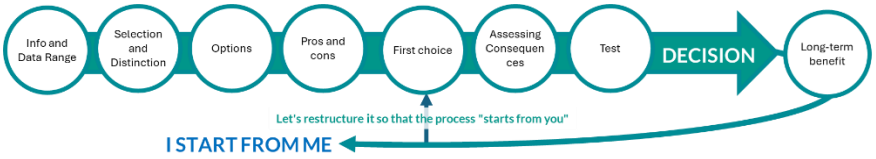

Fig. 4. Choice process built by the students during group work.

The example in Fig. 4 shows how much the students have achieved in designing the choice process. We have proposed 2 work steps. The first consists in dividing the classroom into groups which are asked to define the choice process. The results acquired by all the groups are finally collected to be used, as input, during further final work, with different groups. Results like this, in which students have reconstructed complex processes such as, for example, that of "informed choice" have led us to ask ourselves which classroom techniques can facilitate the acquisition of new knowledge and skills useful for career orientation, be it university or professional. We have also focused our research on identifying which techniques to adopt, in the classroom, to facilitate the acquisition of new strategic skills. The opportunity to explore new methodologies to be integrated into the students' training courses was provided by the possibility of organizing, as a University, an experimental course. In Italian training models, as in other countries around the world, in fact, there is a compulsory activity, to be carried out during upper secondary school, which is part of training on transversal skills. The activities that fall under "apprenticeship/internship/traineeship" are called Pathways for Transversal Skills and Orientation (PCTO) [12]. PCTOs are therefore pathways that schools can join to help their students acquire the transversal skills in different contexts, necessary for their growth. Below are the main points of the training project, at the basis of the PCTO that we have proposed and which traces the format used in the classroom during our innovative laboratory of the Faculty of Civil and Industrial Engineering Sapienza, aimed at preparing and equipping, with the appropriate soft skills, future engineers in proposing themselves on the market and entering the world of work [13].

1. **Premises:** to talk about informed choice means to provide students with the opportunity to work on the underlying process to identify, in each one, what are the drivers that guide and facilitate the flow of elements necessary for the choice itself.
2. **Objectives**: to transmit skills and measure them, as per the PCTO format; to provide tools to develop critical thinking and discernment skills; to monitor personal development.
3. **Method:** the proposed and followed method, as well as being based on the COACH_ING model, was enriched with new elements: stimuli on contexts and relationships [14]; association parameters/indicators (MCs) submitted at precise times, following appropriate mandates (direct knowledge of the CPs, direct interpretation); involvement of coaches, mentors and professionals to build the concept of reliable references and containers of specific skills.
4. **Tools used:** In addition to those used in university interventions [13], assessments were integrated, carried out with precise times and methods, during the development path built on instructions, tasks and projects, and group works.
5. **Data:** The data collected had a double value: allowing effective monitoring of the students' path and stimulating, in them, awareness and self-efficacy of the elements learned (C_I skills and MCs).
6. **Final test:** The final test, part of the model standard, was enriched by group comparison, for self-evaluation and choice of one's own kit, and a feedback form suitable for everyone (professionals, students and mentors), representative of what was most meaningful to the participant, as a student, mentor, professional, etc.

Today, the trend of new possible orientation models is aimed at developing trajectories under the guidance of critical thinking, inclusion, social and ecological justice. Our proposal has, in fact, been enriched with the "relationship context" stimulus precisely to develop sensitivity towards the community and the surrounding environment [15]. Our research aimed, therefore, to deal with new questions, to validate the proposals of the model and the classroom process, which are reported below:

- How can the analysis of feedback (outcomes) activate the desire in students to cover distinct roles based only on their own aptitudes and not on tasks assigned exclusively through the evaluation of only one part of their knowledge such as, for example, the technical ones?
- Is it possible that simple stimuli, in various work contexts and attitudes towards relationships with others, can highlight the predisposition for one role rather than another?
- Can professional profiles characterized exclusively by MCs be defined and thus prepare students to consciously face the world of work?

These objectives were pursued by classifying MCs closely linked to professional categories defined in our previous work.

The analysis of the comparison of assessments and feedback on MCs allows us to obtain information on what the characteristics, aptitudes and potential inclinations of everyone are, allowing us to work towards acquiring awareness of these personal qualities. After years of observation and study, as well as data collection and analysis, we

believe that the concept of complex capabilities, which we call Macro Capabilities, is very close to aptitudes, seen as a complex of individual skills. This led us to work on MCs as a basis for our work. The awareness that MCs are a combination of individual skills constitutes a functional training basis for the development of individual and complex parts. Clearly both the individual skills and the MCs are linked to specific assessments. Our aim is to be able to use assessments on MCs in the future as indicators of tendencies to take on possible professional profiles among those proposed. The reconstruction and combination of the data collected in the interventions of recent years has led us to results, in terms of professional tendencies [10], which have been validated and shared with those who have followed the entire path. In fact, at the basis of our experimentation on MCs and Professional Categories (CPs), there is the study of the relationship between the intrinsic links between the 16 skills, which make up both the MCs and the CPs. We believe that, over time, this inter-correlation will be more evident and that these links will be attributable to a mutual influence between them. This process will lead to the definition of sets made up of specific MCs and related professional categories. In the context of training for future engineers, this consists in the possibility of adopting an integrated classroom methodology in which the desire to fill roles based on transversal and not just technical skills is also enhanced.

3 Approach

Our training experimentation targeted high school students and engineering students. It began by stimulating individual resources to highlight aptitudes and abilities. Participants then engaged in classroom sessions and company visits to gain awareness of working contexts and prospects. Finally, through self and mutual assessment, specific parameters were monitored during experimental laboratories where participants designed innovative ideas. The aim was to enhance the participants' ability to present themselves on the market by acting on their skill sets and constantly monitoring growth indicators. The objective of the individual interventions in the laboratories was to cross-reference the collected data, particularly from assessments. These results underscore how leveraging individuals' skill sets (skills, abilities, and personal characteristics) enables new generations of engineers to better position themselves in the market. The developmental journey involves continually monitoring skills identified as growth indicators. This approach is also designed with consideration for individuals' personal desires to work within specific contexts and foster relationships with others.

In particular, the training theory used in the classroom is divided into several components. At the base, we use Implicit Theory, to give relevance to the contents of the individual [16], which takes the form of a sequence of stimuli and procedures in the classroom with which the students are involved. We begin with work on the individual (Step 0 - Starting from the self), Fig. 2, proposing a reflection, for example, on the ideal context and on the relationship, one wants to undertake with others, in terms of proposal, help, support, service, sales etc. We therefore resort to stimulus questions, role-playing games, group work in which they are asked to solve problems, interpretations of skills, subsequent knowledge of elements to be attributed to roles and functions, as

well as the construction of CPs, following and during, a discussion with organizations and companies. The next step begins with the transmission of the C_I. The skills are tested in the group work and represented by the students. Subsequently, a reflection is conducted on the professional categories and their respective tasks and the attribution of MCs to the individual CP is requested. The work on C_I, MC and CP is conducted through group works, in which contexts and scenarios, as well as work mandates and rules of the game, are modified, in order to develop and grasp the different aspects of what is the subject of the work. Furthermore, students are invited to have direct experiences through which they can experience the world of work first-hand, through visits to companies or classroom meetings with professionals. During these moments, students can compare themselves with those who really hold the roles they have reflected on and consequently re-evaluate how much the MCs most representative of a given role may vary. The work starts from the individual skills of the model to allow a broader vision of what is required by the world of work. Moving on to the MCs, we have the possibility of evaluating each MC as an entity born from a combination of micro elements and this allows, on the one hand, to identify characteristic aspects of a new Macro Capability (not present at the moment among the 8 that have been proposed) and, on the other, to facilitate critical thinking in order to know how to combine them with one professional role rather than another. At the onset of the laboratories, students underwent self and mutual assessments to evaluate their MCs. Building upon the previous work presented at ICL 2023, which defined sets of MCs specific to each professional category, students focused on refining their skills and competencies. Towards the conclusion of the courses, students conducted additional assessments focused on their MCs and determined which professional categories aligned best with their aptitudes. These self-assessments covered 16 skills, forming the foundation of our COACH_ING model, encompassing both relational skills typical of coaching, and the programmatic and systems skills essential for engineers, such as project management capabilities involving technical and social problem-solving [17]. All interventions were implemented using our COACH_ING training model, incorporating dedicated tools for self-evaluation of MCs. Our experimentation persists, involving diverse classes and samples to enrich the model with data, thereby enhancing its utility for monitoring, facilitation, and career guidance. The laboratory cycle encompassed 30 hours in classroom settings and 15 hours at technology companies. Lessons and meetings typically spanned a maximum of 4 hours per week to ensure effective assimilation and processing of stimuli.

4 Experimentation with future engineering students and actual outcomes

To broaden the spectrum of our experimentation on MCs and professional categories, we wanted to focus on the current context in which the new generations live. Today's young people are equipped with the ability to connect multi-channel and have an infinite amount of information at their disposal [18]. The consequence, however, is that they are not always able to identify certain sources; they are able to propose multiple solutions but show uncertainty when faced with the choice and evaluation of one

opportunity over another [19]. Thus arises the need to make the energy of their ideas and potential flow, making educational experiences available aimed at strengthening fundamental aspects for their growth and for their presence in the world of work. The elements that are the basis of our work during our interventions are: the intervention planning techniques, the laboratory and teaching activities, transmitting the concept of taking responsibility for the instructions received and homework. The structure of our interventions arises from a method based on defined objectives and, therefore, on the results we want to achieve. In this regard, over the years of experience, we have made many steps forward; moreover, every single intervention had the objective of transferring value, and this allowed us to integrate, into our model, elements that represent new tools for growth, exercise and evaluation of the individual. As a Faculty of Engineering, after the experiences in previous years, we have therefore designed a new PCTO, having the concept of vocational choice for one's future as a guideline; the title of the course was "A tool kit for choosing a future course of study" and was designed to build new horizons and new trajectories to open minds and transform ideas into actions and achievements [20]. In the following table, we can focus our attention on the data collected in the latest experiments in which we compared not only the students of our university laboratory, fellow engineers from the Council and professionals linked to the technological world, but also the new target represented by PCTO secondary school students. The data were collected during the group works in which two different techniques were used: re-engineering (direct reconstruction through the descriptions of the MCs and Professional Categories) and the interpretation of roles in the group. The common objective in this phase of the development process was to identify what the prevailing MCs were, according to the target audience, within specific professional categories. The group work was of two types:

- Engineering designing of the profession: participants were provided with some brief descriptions of the professional categories and the MCs to be associated with them. A maximum time of 25 minutes was given to complete the assignment of 2 MCs for each professional category.
- Case Study (CS): participants were provided with a description of a professional scenario in which an event (problem) occurs and descriptions of some professionals who operate within the same scenario. A maximum time of 25 minutes was given to simulate a meeting, where everyone assumed the part of the assigned professional, so that a possible solution to the problem exposed was identified. Following the meeting, participants were asked to assign the two MCs that they consider distinctive of the professionals interpreted during the CS.

Below are the aggregate data resulting from the work carried out:

Table 1. Aggregate data resulting from the group works and case studies

PROFESSIONAL CATEGORIES	FROM OUR DATA	FROM STUDENT'S DATA 1 (PCTO KIT)	FROM STUDENT'S DATA 2 (LAB2024)	FROM PROFESSIONAL'S DATA (ING COUNCIL)	% OF CONGRUENCE
RESEARCH AND DEVELOP	FLEXIBILITY, HIGH ACHIEVING	FLEXIBILITY, OPTIMISM	INSPIRATION	CONFIDENCE, INSPIRATION	17%
SALES AND MARKETING	HIGH ACHIEVING, CONFIDENCE	CONFIDENCE	CONFIDENCE	COURAGE, FAST THINKING	33%
OPERATION	HIGH ACHIEVING, COURAGE	FAST THINKING	RESILIENCE	FAST THINKING, HIGH ACHIEVING	17%
FREE-LANCE AND ENTREPRENEURSHIP	FAST THINKING, OPTIMISM	FAST THINKING	COURAGE, INSPIRATION	FLEXIBILITY, OPTIMISM	33%
PROJECT MANAGER	CONFIDENCE, COURAGE	COURAGE, HIGH ACHIEVING	COURAGE	CONFIDENCE, HIGH ACHIEVING	50%
FINANCE AND CONTROL	FAST THINKING, COURAGE	N/D	FLEXIBILITY, FAST THINKING	COURAGE, HIGH ACHIEVING	33%
HUMAN RESOURCES	FLEXIBILITY, CONFIDENCE	CONFIDENCE,-	CONFIDENCE, OPTIMISM	FLEXIBILITY, CONFIDENCE	67%
SUPPORT SERVICES	FAST THINKING, INSPIRATION	N/D	HIGH ACHIEVING	FAST THINKING, HIGH ACHIEVING	17%

LEGEND	
	ALL IN COMMON
	ONE IN COMMON
	NONE IN COMMON

The data were compared, as shown, with those defined within the reference model. Color coding was applied to represent the cases in which the participants' data correspond to those of the model for both MCs (green), in which only one of the two MCs corresponds (yellow) and the one in which the association is incongruent (orange). The last column shows the percentage of congruence of the data of all participants (PCTO students, Laboratory students and professionals). The level of congruence of the data with the definition of the model is not to be understood as a judgment on the correctness of the same, but rather as a further opportunity to study the MCs linked to the professional categories by analyzing the perception of different targets. The data shows a slightly higher level of congruence with the model in the professionals' responses, however, in this respect, the difference with the student data is minimal. What is most indicative, however, is the total level of congruence of the individual professional categories. The most congruent professional categories are “Project Manager” (50%) and “Human Resources” (67%). This data could be indicative of a greater familiarity of the participants, despite their differences, with the professional categories (management is also necessary in everyday life as well as relational skills), which are therefore more understandable and in which the participants could have managed to empathize more. Given that the study carried out is focused on "perception" (after all, the students do not have consolidated professional experience to express a judgment born from their own experiences), the objective of the research is also to understand the real need to inform future generations (and perhaps even the professionals themselves) on the nature of the various professional categories. To guide individuals towards conscious choice, "awareness" and a sufficient understanding of the opportunities available to them are necessary. The studies carried out to date, of which the latter is also part, suggest a real need to intervene on these aspects to allow students and professionals to orient themselves towards the sectors and professional roles most capable of enhancing the skills they possess. The need is therefore reconfirmed to proceed with research for the creation of clusters of descriptive skills/competencies of the professional categories which to date are classified mainly through the sector to which they refer and the tasks/responsibilities they entail. A classification based on capabilities and skills would allow people, who wish to orient themselves, greater awareness to make their own choice, using, as evaluation dimensions, their own personal characteristics (internal and, therefore, easier to perceive) rather than descriptive nomenclatures of the various professions (external and, therefore, which require research and study to be understood). In summary, the partial identification of the skills attributable to the tasks by secondary school

students is due to their distance from the professional world, unlike university students who rely on greater, albeit limited, knowledge. However, the adherence, albeit partial, on the part of professionals is highlighted. This last result unfortunately confirms what was found, showed in Fig. 1. The technical professional today is little aware of the role he plays both because he did not receive, during his studies, training on business organization and organizational structures, and because, in such a dynamically complex world, everyone is transferred from one position to another, often, without due information and structured and recognized involvement. The advantage of these works is that it allows everyone, at any age, to know the individual elements of the method, favors the opening of minds to other opportunities, shows possible future scenarios, makes it possible to achieve our goal and allows those who participate to carry out a thoughtful and conscious choice. To the above, we add both being able to evaluate oneself, based on growth parameters, and allowing the student to monitor and evaluate himself during the entire intervention; above all, we work to acquire a monitoring and analysis methodology that provides a perception of what we are and what we want to become.

5 Summary

New elements have been incorporated into our research presented at ICL23. The goal was to empower students to construct their own skill set for navigating their career path. Classes involved engaging activities and group work centred on the contemporary landscape of work, marked by emerging technologies, artificial intelligence, inclusion, and sustainability. The findings revealed a notable disparity between the sets of MCs identified in the self-assessments at the culmination of the courses or paths, compared to those initially recognized by the students. In many instances, students were unaware of the existence of certain MCs. Through the analysis of their personal MCs, students could discern the professional categories that most closely aligned with their skill sets. This analysis of the results further demonstrates how the Train to Career method, utilizing the educational tools of the COACH_ING model, likely aids new generations of engineers in crafting careers that resonate with their individual attitudes and allow for exploration of new trajectories. The monitoring process also influenced the communication micro skills utilized in presentations and personal proposals. Additionally, the results indicated a growing speed of thought among the new generations, alongside a heightened orientation towards critical thinking, facilitating optimal reshaping and reorienting of choices. In a broader vision, wherein universities and schools aim to equip the new generations of engineers with the development of their transversal intelligences, we aspire to enhance future research by gathering data from our former students, who are now professionals. Indeed, for research purposes, it would be beneficial to conduct individual assessments on professionals who have occupied diverse roles, even those distant from their specialization. This exploration would shed light on how their personal set of MCs, integrated and acquired through the innovation of our training model, influences their career trajectory. Assessment processes and analysis of results enable the new generations of engineers to boost their motivation, expand their

horizons, and embrace new and continuous learning opportunities. The elements, which are increasingly indispensable in today's dynamic world of work.

Finally, the data collected during the trial also provided a further clear indication of the increasing speed of thinking among the new generations, together with a strong orientation towards critical thinking, facilitating the optimal reshaping and reorientation of choices. We intend to introduce the time factor as a variable of interest, as a measure of execution of group work in which results and projects are produced. These classroom assessment processes, and subsequent analysis of results allow new generations of engineers to increase their motivation, expand their horizons and embrace new and continuous learning opportunities that allow everyone to choose the professional they want to be. Among the new tools to be introduced are: cards representing skills, assessment kits, logbooks based on digitized tables to provide automated comparison and analysis reports. Among the classroom techniques, the feedback model for the final exam and the data on mentors, managers and leaders introduced this year could be enriched. Even the collection and combination of data from the MCs attributed to the CPs can provide an interesting tool which, based on the selection of MCs, could indicate the professional tendency. Precisely for this reason we want to move forward and free ourselves from stereotypes and professional labels and we want to focus only on tasks and know-how, putting aside further biases by prioritizing direct work on mastery and know-how by concentrating on the "professional verbs" (selling, providing, design, support, ability to transmit, etc.). A further element that we must finalize is the definition of basic evaluation grids to be provided to teachers of any subject, focused on the quantities linked to learning standards (Dublin Descriptors) [21], in which to note the degree of acquisition of the same by the students, indicating the level of mastery expected at the end of the course. The real strength of the tools that we talk about and that we want to build is that they are assessments or stimulus questionnaires. The student is not required to perform but to participate with others; our training model aims to empower the students of tomorrow with MCs suited to the professional horizons they aim for.

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