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HOW TO IMPROVE EMPLOYABILITY IN ENGINEERING STUDENTS: A STUDY ABOUT STUDENT CAREER PLANNING AND PERCEPTION OF LABOR MARKET

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Abstract *Socio-economic factors such as unemployment among young adults have influenced graduates' perception of the labor market and their career planning. In this context, education plays a central role and in particular there is the need to understand which are the most important soft skills and competences that universities should promote to enhance employability among students. The aim of this paper, therefore, is to investigate engineering student perception of labor market and career planning. Data was collected by means of a questionnaire administered to engineering students of the University of Padova and analyzed by applying suitable machine learning models to investigate the relationship between student perception of the labor market and career planning, and some other factors, i.e. general information, self-perceived employability, career proactivity, and career control. Results of the analysis and their educational and social implications are presented and discussed.*

Keywords: *Employability, Engineering, Machine learning, Labor market, Career planning.*

1. Introduction

Understanding higher education students' perceptions of labor market demands has an effect on students' self-perceived employability, career proactivity, and career control. This is particularly of interest from an educational point of view since it can give useful insights about what students need to better develop their employability. In the literature there has been much discussion about graduate employability. It is referred to as "the capacity to gain initial employment, maintain employment and obtain employment if required" (Hillage and Pollard, 1998), or the ability to find and retain a graduate-level job or move between jobs if required (Yorke, 2010). In some studies, individual employability is considered to be a complex dimension made up of various factors, such as professional

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identity, spanning social connectedness, work and life experience, and career self-management (Jackson, 2016; Tomlinson, 2017). Other research focuses on the ability of graduates to develop transferable skills (Cascio, 2019) to guarantee them a 'sustainable employability' (Monteiro and Ceu Taveira M. & Almeida, 2019). It is a construct related to a) 'career adaptability', i.e. "the tendency affecting the way an individual views his or her capacity to plan and adjust to changing career plans [...] especially in the face of unforeseen events" (Rottinghaus et al., 2005), and b) the agency of graduates and their adaptive and proactive resources necessary to move into employment (Montgomery and Cote, 2003). In employability literature, the effect of external factors such as labor market demands, economic trends and recruitment characteristics, has also been investigated (Hillage and Pollard, 1998; Rothwell and Arnold, 2007), but little research has been carried out on student perception of the labor market during the pandemic, and the effect on their career planning.

Youth unemployment has always been a key issue in policies of the European Commission (2009) and the Organization for Economic Co-operation and Development (OECD, 2012) that aimed to promote strategies and economic reforms that provide a highly qualified labor force with the research and development capabilities to contribute to innovation. Despite this, unemployment among young adults has continued to be a result of various factors: globalization, technological development, rapid transformation of work and professions; the distance and virtual conditions of jobs; boundaryless careers (Lo Presti and Pluviano, 2016) with consequent professional instability (Gevaert et al., 2018; Ingusci et al., 2016); the misalignment between skills that young people have at the end their learning path and those required by the labor market; the growth of the overeducation phe-nomenon with young people being underpaid, and their skills and competences undervalued (Bol et al., 2019; Duncan and Hoffman, 1981; Romero et al., 2017). The onset of the COVID-19 pandemic contributed to a worsening of this precarious situation and to increasing the dynamism of labor market, where the digital disruption and organizational and production changes prevail over any stability (Kaneklin and Gilardi, 2007) and, independently of their attained education, people must be ready to move from one role and set of activities to another, and abandon the traditional long-term employment idea. Before the pandemic, vari-ìous studies were carried out on student perceptions of the labor market, and on career planning/control behaviors, proactivity and self-perceived employability. Various results in the literature were registered in relation to students' labor market perceptions. Tomlinson (2008) highlighted how, given the complexity of the

labor market, students question the value of academic qualifications for finding jobs. Equally, Roulin and Bangerter (2013) reported that students recognize the importance of developing positional advantage to stand out and increase employment possibilities. This negative perception of the labor market was also identified in Jackson and Tomlinson (2020), in which students appear to be aware of the competitiveness of the world of work. On the other hand, some studies show that students consider the challenging labor market to be an opportunity rather than a threat (Deoitte, 2018). Malizia (2016) revealed that 60% of Italian graduates seem to have positive labor market perceptions in terms of the flexibility of their work and the correspondence between training and job obtained, but are less satisfied with the economic aspects because the job they obtain is often less paid than the quality of their professional profile merits. Students' self-perceived employability is linked to their individual beliefs regarding successful gaining of employment. Rothwell et al. (2008) investigated this by incorporating individual self-beliefs, student perceptions of university reputations and credibility of their chosen field of study into their measure, as well as the state of the labor market, demonstrating that self-perceived employability depends on both internal and external factors. Jackson and Wilton (2017) identified that positive self-perceived employability was linked to low levels of awareness of the uncertainty of the labor market. Career control, career planning, and proactivity are further evidence individual career behaviors. The ability to control one's career is an expression of self-regulation strategies and personal control (Coetzee and Stoltz, 2015; Savickas and Porfeli, 2012). Perceptions of career control can differ between graduates in employment and those who are not, but can also depend on the type of degree obtained (Deoitte, 2018). In fact, professional degree programs (e.g., Engineering, Health) compared to generalist degree programs (e.g., Art, Humanities) are linked to better employment outcomes (Karmel, 2015; Tino, 2021). Career planning is based on the formulation of goals and strategies to achieve the aspired-to career. Determinants of career control were identified as resources, agency, personal motivation and expectations (Lent and Brown, 2013), but also internal locus of control and self-efficacy (Fugate et al., 2004). Proactivity is associated with career initiative, attitude towards change and learning (Spitzmuller et al., 2015), towards finding opportunities and persevering for the achievement of goals (Bateman and Crant, 1993). It is related to entrepreneurial intent (Zampetakis and Moustakis, 2006, 2007) and individuals' adaptability to their environments (Crant, 2000). Despite the large number of interesting studies on different career concepts, only one was found to look at the relationship between student labor market percep-

tions, self-perceived employability, career planning/control, and proactivity (Jackson and Tomlinson, 2020). Although the authors provided empirical results on student perceptions of labor market registering a holistic impact on the most important career dimensions, they did not consider some personal and contextual factors as predictors of student career behavior, factors that are recognized in the literature as determinants of people's career orientation. These factors are the role of the university and high school learning experience, career modelling, family support, expectations, and personal career interest (Buday et al., 2012; Dasgupta and Stout, 2014; Ferry et al., 2000; Kim and Seo, 2014; Lent and Brown, 2013; Lent et al., 1994; Vargas et al., 2018). In fact, employers prefer prestigious universities in which students should be better prepared and ready for the world of work; students in the most highly rated universities have higher expectations in terms of employment in brand organizations (Rothwell et al., 2008). School or university learning experiences nurture students' interests and reinforce outcome expectations through a continuous internal (self-efficacy) and external (from others) recognition process. Career outcome expectations support people's behaviors and motivation when facing challenges. They are connected to people's beliefs about consequences of activity engagement and in terms of anticipation of some results (e.g., money, social recognition and approval, self-satisfaction) (Kim and Seo, 2014). Finally, career modelling and family support influence students' academic and career development, as well as career aspirations (Dasgupta and Stout, 2014). Based on the previous rationale, an Italian version of Jackson and Tomlinson (2020) questionnaire was developed and administered. It aimed to: investigate how labor market perceptions influence student career behaviors; explore student engage-ment in career planning in the context of a threatened world of work; underline students' perceived needs to develop their employability in terms of soft skills and capabilities.

Knowing how students perceive the current labor market and its effect on their career planning and career control will provide useful information for all involved stakeholders: (i) students will have information on their career development process and the achievement of their career outcomes by a leaded reflection on the alignment between their perceptions and the real opportunities and needs of labor market. It's a reflective process that helps them to become more aware of their career planning and control; (ii) universities can reflect upon their level of success, on the impact on graduate employment outcomes, and upon the possibility of introducing work-based teaching methods developed in partnership with industry to better prepare students for their future careers and employment (Dee-

gan and Martin, 2017; Frison, 2015; Tino, 2018); (iii) employers, who can learn about student career motivations and concerns which will assist when recruiting and engaging with graduates.

Thus, by exploring some career concepts, and using the scale developed by Jackson and Tomlinson (2020), this study sought to investigate higher education students' perceptions of the current labor market and the effect on their employability, pursuing two research objectives which essentially represents our data challenges:

(i) to explore student perceptions of current labor market demands and the factors that determine them;

(ii) to know what elements affect student career planning.

Collecting this data will support our understanding of the knock-on effects of labor market demands, student labor market perceptions, and student career planning and control. Furthermore, it will shed light on the opportunities for higher education institutions to design career development learning paths that match graduate skills and knowledge with labor market demands and align graduate employability competences with university-to-work transition processes. Of course, in order to achieve these objectives, it is essential to conduct appropriate statistical analyses with the aim of accomplishing our research goals. Our study was carried out at an Italian university using data collected from a survey administered to students at the faculty of Engineering.

The paper's structure is as follows: Section 2 presents the questionnaire, along with a description of the data. In Section 3, we explain the machine learning approach, as well as the results in Section 4. Final remarks are provided in Section 5.

2. Data and measure

2.1. Data description

The survey was administered to students of the faculty of Engineering. The software Limesurvey was used to collect data between March and May 2021. Students were sent a personalized link to their university email account and were selected from the final year (third-year) of undergraduate courses, from both years of Master's degree courses, and from the last three years of single-cycle courses (i.e. 5-year courses resulting in a Master's degree). These cohorts were selected by virtue of the belief that students at these stages of their university journey are

more aware of their career goals and the challenges of university-to-work transition than the other undergraduates. In comparison to other similar studies on employability in Engineering, such as those by Chou and Shen (2012), Idkhan et al. (2021) and Howell et al. (2023), which considered samples ranging from 130 to 530 respondents, our sample size is notably larger and may provide more robust insights.

2.2. Definition of the adopted measure

This study adopts both the English version of the scale (Jackson and Tomlinson, 2020) and the Italian version (Tino, 2021), developed through back translation (Brislin, 1970). The measure aims to register the relationships between student labor market perceptions and career planning, proactivity and employability.

In particular, the following will be considered:

- If there are greater negative perceptions of the labor market associated with
  - a lower level of self-perceived employability
  - a lower level of career control
  - a greater level of proactivity
  - greater commitment to developing positional advantages;
- If there is a positive association between
  - Self-perceived employability and career planning
  - Proactivity and greater career planning
  - A greater level of career control and career planning
  - A greater role of contextual factors and career planning
  - A greater role of personal factors and career planning.

The measurement is made up of 5 dimensions (perceived labor market conditions, self-perceived employability, career control and planning, proactivity, and developing positional advantage) and 28 items on a 5-point disagree-agree Likert scale. It also includes items on participants' characteristics such as gender, age, residency, study field and stage, level of employment, and parental occupation. The latter was useful to identify students' socio-economic status. With respect to Jackson and Tomlinson's study, additional personal and contextual variables were

considered because of their effect on individual career behaviors (Lent and Brown, 2013): family support, that considered the level of encouragement and recognition provided by families; the role of school focusing on the curriculum, in-school and out-of-school experiences, and student-teacher relationships; the role of the university, investigating the influencing role of the student-teacher relationship and learning experiences on career choices and self-awareness; career modelling, focusing on the career role and experiences of parents; expectations in relation to social recognition, career and job finding opportunities; personal career interests focusing on decision-making processes supported by a personal interest in a field of study, or specific careers and personal development. Testing of the psychometric properties of the scale was presented in a previous study (Tino, 2021) in which the inter-item consistency of scales was tested using Cronbach's alpha ($\alpha > 0.7$). Further operationalized contextual and personal factors considered for the group of engineers were: skills in the world of work, developed skills, skills to be promoted by the university and activities to be promoted by the university to support employability.

2.3. Descriptive statistics

Regarding the sample utilized for the analysis, the majority of participants were aged 18 to 25 (constituting 84% of the sample), although a notable portion was aged 26 to 30 (13%). Moreover, a significant proportion of the sample identified as male (74%), while a smaller segment consisted of international students (3%). The majority were enrolled as students, yet a quarter of the sample comprised student workers, indicating that some participants already had prior experience in the labor market. In the questionnaire, participants respondents were asked to express their opinions on two key performance indicators (KPIs): the current state of the labor market and career planning. Additionally, they provided insights on various other dimensions including proactivity, perceived employability, career control, and skills that they consider important. Moreover, their decisions regarding course of study/career paths, expectations, the role of school and university on curriculum and career choices, the development of a positional advantages and the activities that universities should promote were investigated. The subsequent paragraph presents the primary findings from the descriptive analysis of these themes. Initially, descriptive statistics and graphical representations of the KPIs are provided, followed by an examination of the remaining aspects.

The first KPI regards the perception of the current state of the labor market. Analysis of the responses showed that 64% of respondents believed there was

a fairly high risk of being employed in a job for which they are overqualified. About 40% of students were concerned about competition and uncertainty in the labor market. The 51% of sample agreed on the difficulty of finding work that students would like to do. See Figure 1 for more details. The second KPI under consideration pertains to career planning. Respondents agreed that they often thought about how to plan their future career and how to explore all potential career possibilities, they are also aware of the future career choices they have to make. They also agreed that they strive to improve their employability. See Figure 2 for more details. In both Figure 1 and Figure 2, responses were provided on a Likert scale ranging from 1 to 5. A score of 4-5 indicates "Agree," 3 denotes "Uncertain," and 1-2 signify "Disagree".

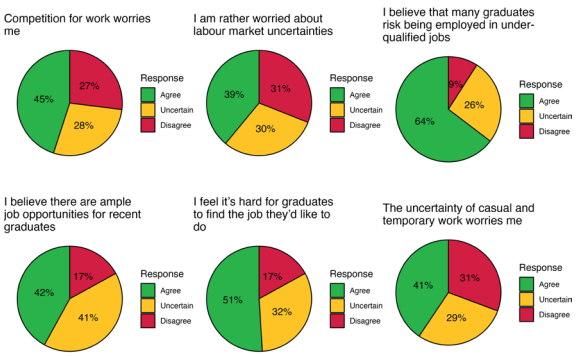

Figure 1: Responses on perception of the current state of the labor market

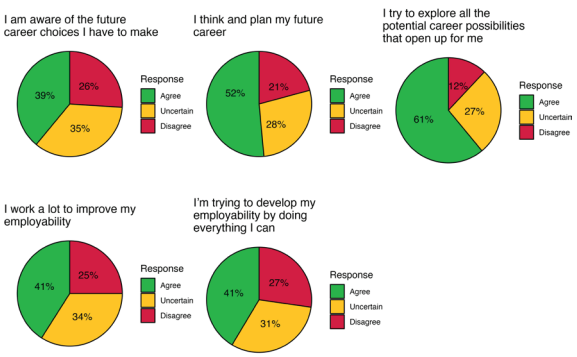

Figure 2: Responses on career planning

Let us now shift our focus to the other aspects addressed in the questionnaire. With regard to proactivity (see Figure 3), respondents considered having a career to be an important aspect of their life (81% of students agreed). Most of the students agreed that they think a lot about their future career (66%) and they are excited to start their career path (75%). With respect to the employability perception (see Figure 3), descriptive statistical analysis revealed that 72% of the sample believed they possessed the skills required by the labor market. They felt confident about the ability to compete in the world of work compared to other graduates (64% of students agreed) and they were convinced that they would be able to find work in their field of study (58%). With regard to career control (see Figure 3), freedom to choose one's own career path was an aspect on which the sample agreed (89%). Moreover, being responsible for one's career and in particular for one's successes or failures were also important to the sample (more than 70% agree with these aspects). A consistant number of students (39%) were uncertain on being able to handle their career setbacks.

Proactivity	
importance_having_career	Having a career is important to me
thinking_future_career	I think a lot about my future career
enthusiasm_start_new_career	I'm excited to start my career path
Employability perception	
skills_importance	I believe that my skills and experiences will be required by the world of work
belief_in_obtaining_job_vs_others	I think I'll be able to compete with other graduates to get a job
belief_in_obtaining_job_after_graduation	I'm sure I'll find work in my field after I graduate
Career control	
career_responsibility	I feel like I'm responsible for my career
career_responsibility_management	Each worker is responsible for managing his or her career
career_failure_management	I think I'll be able to handle setbacks in my career
freedom_in_career_choice	The freedom to choose my career path is important to me
responsibility_for_career_success_failure	I am responsible for the success or failure of my career

Figure 3: Variables considered in the questionnaire

Part of the questionnaire concerned the analysis of skills and activities that respondents consider important in the world of work (see Figure 4).

The skills considered most important were, in order of importance, analytical thinking and innovation, ability to solve complex problems, critical thinking, active learning, creativity, originality and initiative. Confirming this, 44% of the sample believed that the university should promote the development of analytical thinking, 40% agreed that the university should encourage development of the ability to solve complex problems, 42% agreed that the university should encourage the development of critical thinking and active learning, and 43% believed that the university should promote creativity, originality and initiative. More information on the skills that respondents think should be promoted at university can be found in Figure 5.

Skills in the world of work	
analytical_thinking_and_innovation	Analytical thinking and innovation
active_learning_and_strategies	Active learning and strategies
solving_complex_problems	Resolving complex problems
critical_thinking	Critical thinking
creativity_originality_initiative	Creativity, originality, initiative
leadership	Leadership
technologies_use	Use of technologies
technological_design_and_programming	Technological design and programming
Resilience_stress_tolerance_flexibility	Resilience, stress tolerance, and flexibility
reasoning_ideation	Reasoning and ideation
emotional_intelligence	Emotional intelligence
persuasion_negotiation	Persuasion and negotiation
Skills to be promoted by University	
university_analytical_thinking_and_innovation	Analytical thinking and innovation
university_active_learning_and_strategies	Active learning and strategies
university_solving_complex_problems	Resolving complex problems
university_critical_thinking	Critical thinking
university_creativity_originality_initiative	Creativity, originality, initiative
university_leadership	Leadership
university_technologies_use	Use of technologies
university_technological_design_and_programming	Technological design and programming
university_resilience_stress_tolerance_flexibility	Resilience, stress tolerance, and flexibility
university_reasoning_ideation	Reasoning and ideation
university_emotional_intelligence	Emotional intelligence
university_persuasion_negotiation	Persuasion and negotiation

Figure 4: Variables considered in the questionnaire

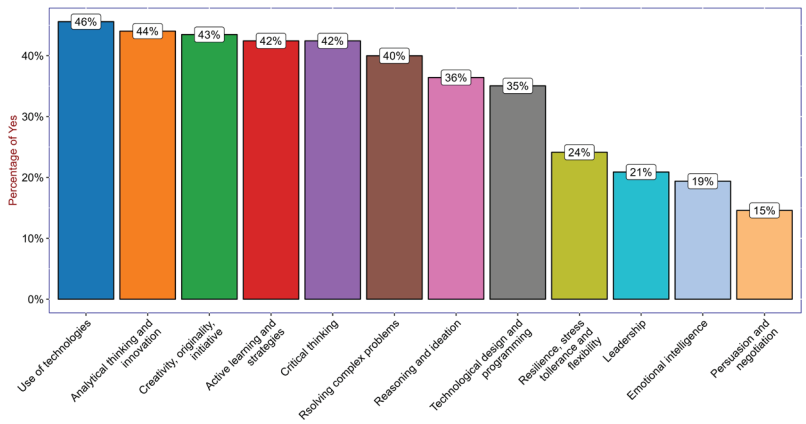

Figure 5: Skills that respondents believe should be promoted at the university

Another set of questions in the questionnaire concerned factors that determine the choice of course of study and career (see Figure 6). Regarding choice of course, the respondents were in agreement that the chosen course of study represents an opportunity for personal development (75%) and represents the desire of following a precise career path (52%), the choice is linked to a personal interest (80%), and that the knowledge and skills provided make it possible to find a good job (77%). Moreover they agreed that family always recognized their ability (74%) and encouraged their choice of study and career (72%). On the other hand,

they seemed to disagree more that the choice is linked to parental influence (66%) or extracurricular experiences (66%).

Among expectations linked to choice of course of study (see Figure 6), the samples agreed with the belief that the chosen course made it possible to find the job best suited to the respondent's preferences (70%). Around 60% agreed that the chosen course made it possible to occupy a position with an active role in society and a socially recognized career.

Choice of university path	
choice_based_on_interest	My choice of studies was determined by my personal interest in the field of study
choice_based_on_desire	The choice of my study path was driven by the desire to follow a specific career path
choice_as_personal_opportunity	The chosen course of study represents for me an opportunity for personal development
good_chances_finding_job	The knowledge and skills acquired during my studies offer me good chances of finding a job
family_encouragement_on_choice	My family encouraged my choices of studies and career
parental_career_influence_on_choice	My parents' career models influenced my choices
choices_based_on_experiences	Extracurricular experiences encouraged by my family helped determine my choices
family_recognition_of_abilities	My family has always recognized my abilities
Expectations	
expectations_for_socially_recognised_career	The chosen path will allow me to pursue a socially recognized career
expectations_for_active_role_society	The chosen path will allow me to occupy a position with an active role in society
expectations_for_pleasant_job	The chosen path will allow me to carry out the work I like the most

Figure 6: Variables considered in the questionnaire

Figure 7 contains questions related to the role of school and university in the choice of curriculum and career. The sample agreed that school activities promoted skills awareness (48%). Moreover the curriculum of the secondary school generated an interest in the choice of the university path (52% of students agreed). On the other hand, regarding the role of the university in relation to career choices, the sample agreed that theory/practice learning experiences strengthen career choices (46%) and generally strengthen the acquisition of awareness of personal skills (43%). They were not in agreement that the relationship with some professors at university strengthen career choices (44%) - only 30% agreed - as well as the relationship with professor at the secondary school strengthen university choice (56% disagreed). The same for the influence due to the peer groups (44% disagreed).

School role	
high_school_role	The secondary school curriculum generated my interest in the chosen path
awareness_abilities	School learning experiences helped me gain awareness of my skills
skill_building	The extra-curricular learning experiences helped boost my skills
University role	
theory_practice_learning_experience	The learning experiences at university that combine theory-practice help strengthen my career choices
learning_experience_improve_awareness	The learning experiences I am experiencing at university strengthen my ability to become aware of my abilities
peer_group_guided_choices	Relations with the peer group have shaped my choices
high_school_teachers_relationship	Relationships with some secondary school teachers influenced my choice
university_professors_relationship	Relationships with some faculty members at the university help strengthen my career choices

Figure 7: Variables considered in the questionnaire

Finally, with respect to the development of a positional advantages (see Figure 8), the sample disagreed that the participation in activities such as student, local and sport club, volunteering and career events, can help to develop a positional advantages (more than 50% of students disagreed in all the aspects considered in Figure 8). While the activities that universities should promote, in order of perceived importance, include: ensuring learning experiences that integrate theory and practice, fostering learning through work-based activities, and creating dialogue with the professional world to provide information about study plans (for the complete list, refer to Figure 8).

Positional advantage	
participation_student_club	Participation in clubs or student associations
participation_local_club	Participation in local club
participation_sport_club	Participation in sport club
volunteering	Participation in voluntary activities
participation_career_events	Participation in career events (seminars, job fairs, etc.)
Activities to be promoted by University	
promote_theory_practice_learning_experience	Ensure learning experiences that combine theory and practice
promote_work_based_activities	Foster learning through work-based activities
promote_dialogue_with_working_world	Create dialogue with the world of work giving information about study plans
provide_experiences_for_measuring_knowledge	Provide experiences for measuring their knowledge and skills
support_students_developing_crossfunctional_skills	Support students in developing their cross-functional skills
support_in_gaining_awareness	Support students in gaining awareness of their skills
promote_skill_active_job_seeking	Promoting skill development for active job seeking
support_development_professional_plan	Supporting students in developing a personal professional development plan
provide_career_coaching_services	Providing career coaching services
support_selfefficacy_development	Supporting students' self-efficacy development
provide_career_path_to_insipire	Providing students with exposure to role models and career paths to inspire them

Figure 8: Variables considered in the questionnaire

3. Machine Learning

3.1. KPIs and Drivers considered

Data collected through the described questionnaire should be properly anal-ysed to meet the objectives of this study, in particular there is the need to find a way to explore student perception of current labor market demands and the factors that determine them and also to understand what elements affect student career planning. Therefore, the focus of the statistical analysis is to understand which drivers have the greatest influence on the two considered groups of KPIs, one group looking at perception of the current state of the labor market (6 items) and the other looking at student career planning (5 items). Figure 9 details the referenced KPIs. We address these issues by leveraging a machine learning approach that involves a feature selection algorithm and some machine learning algorithms for classification.

Perception of the current state of the labour market	
graduate_opportunities	I believe there are ample job opportunities for recent graduates and graduates
concern_about_competition	Competition for work worries me
risk_underqualified_job	I believe that many graduates risk being employed in under-qualified jobs
difficulty_finding_job	I feel it's hard for graduates to find the job they'd like to do
job_uncertainty	The uncertainty of casual and temporary work worries me
job_market_uncertainty	I am rather worried about labour market uncertainties
Student career planning	
planning_future_career	I think and plan my future career
future_career_choices	I am aware of the future career choices I have to make
explore_career_possibilities	I try to explore all the potential career possibilities that open up for me
improve_employability	I work a lot to improve my employability
develop_employability	I'm trying to develop my employability by doing everything I can

Figure 9: KPIs considered in the model

Using the set of variables described in Section 2, we obtained a subset of variables by applying a feature selection algorithm, namely Boruta. This algorithm allowed us to understand which variables impacting upon the KPIs of interest are the most relevant. Certainly, in many practical classification scenarios, we often encounter a large number of features. However, it's not uncommon for a portion of these features to be irrelevant for the classification problem (Kursa et al., 2010) and their relevance may not be evident in advance (Kursa and Rudnicki, 2010a). That's why the use of a selection algorithm can be useful. In short, the Boruta algorithm is based on the random forest classification algorithm which is used to iteratively classify features as "important" or "unimportant" based on their significance, for a more detailed explanation of the steps see Kursa and Rudnicki (2010a). In particular, we used the `Boruta()` function from the R package Boruta (see Kursa and Rudnicki (2010b) for more details), setting the maximal number of importance source runs to 300 (i.e. `maxRuns = 300`) and using the Random Ferns importance function to obtain attribute importance (i.e. `getImp = getImpFerns`). The relevant identified drivers are listed and described in figure 10.

3.2. Machine learning model description

Our analysis considers two sets of response variables, or KPIs, and a set of input variables, i.e. the drivers (see Figure 9 and Figure 10). The aim of this analysis is to firstly understand which drivers have a relevant impact on the outcomes, and secondly understand which type of impact the drivers have (positive, negative or quadratic impact) with regard to the KPIs. We've treated all the KPIs as binary variables. Initially, they were collected as ordinal variables on a Likert scale of 1 to 5. However, we transformed them into binary variables using class **T2B** for responses equal to 4 and 5, while responses falling outside this range were categorized as **Others**. Essentially, the response variables are now considered binary

General information	
gender	Gender
age	Age group
study_stage	Year of course attended
highest_parental_occupation	Highest employment position occupied by one of your parents
student_working_status	Student working status
Employability perception	
skills_importance	I believe that my skills and experiences will be required by the world of work
belief_in_obtaining_job_vs_others	I think I'll be able to compete with other graduates to get a job
belief_in_obtaining_job_after_graduation	I'm sure I'll find work in my field after I graduate
Career control	
career_responsibility	I feel like I'm responsible for my career
career_responsibility_management	Each worker is responsible for managing his or her career
career_failure_management	I think I'll be able to handle setbacks in my career
freedom_in_career_choice	The freedom to choose my career path is important to me
responsibility_for_career_success_failure	I am responsible for the success or failure of my career
Positional advantage	
participation_student_club	Participation in clubs or student associations
participation_career_events	Participation in career events (seminars, job fairs, etc.)
Skills to be promoted by University	
university_analytical_thinking_and_innovation	Analytical thinking and innovation
university_active_learning_and_strategies	Active learning and strategies
university_solving_complex_problems	Solving complex problems
university_critical_thinking	Critical thinking
university_creativity_originality_initiative	Creativity, originality and initiative
university_technologies_use	Use of technologies
university_reasoning_ideation	Reasoning and ideation
university_technological_design_and_programming	Technological design and programming
Choice of university path	
choice_based_on_desire	The choice of my study path was driven by the desire to follow a specific career path
good_chances_finding_job	The knowledge and skills acquired during my studies offer me good chances of finding a job
parental_career_influence_on_choice	My parents' career models influenced my choices
choices_based_on_experiences	Extracurricular experiences encouraged by my family helped determine my choices
Expectations	
expectations_for_socially_recognised_career	The chosen path will allow me to pursue a socially recognized career
expectations_for_active_role_in_society	The chosen path will allow me to occupy a position with an active role in society
expectations_for_enjoyable_job	The chosen path will allow me to carry out work I enjoy
Activities to be promoted by University	
promote_theory_practice_learning_experience	Ensure learning experiences that combine theory and practice
promote_work_based_activities	Foster learning through work-based activities
promote_dialogue_with_working_world	Create dialogue with the world of work giving information about study plans

Figure 10: Drivers considered in the model

outcomes. As such we used a classification model to predict the responses of the KPIs split between the two created classes: T2B or Others.

We consider several machine learning models which may suit the purposes of the analysis. In particular we consider: support vector machines with radial ba-sis function kernel (`svmRadial`), random forest (`rf`), generalized linear model (`glm`) and `glmnet`. To optimize hyperparameters and identify the best-performing model, we leverage 5-fold cross-validation. We use cross-validated AUC as the performance metric, choosing the model with an AUC closest to 1. We repeat this model selection procedure for each KPI in our analysis (see Figure 11).

perceptions of the current state of the labour market				
	glm	**svmRadial**	**rf**	**glmnet**
graduate_opportunities	0,7300	0,7343	0,7369	0,7463
concern_about_competition	0,7042	0,6989	0,6990	0,7144
risk_underqualified_job	0,6155	0,5981	0,5938	0,6139
difficulty_finding_job	0,6779	0,6860	0,6935	0,6902
job_uncertainty	0,6625	0,6684	0,6630	0,6752
job_market_uncertainty	0,7231	0,7174	0,7133	0,7190
students' career planning				
	glm	**svmRadial**	**rf**	**glmnet**
planning_future_career	0,7287	0,7317	0,7282	0,7395
future_career_choices	0,7227	0,7413	0,7390	0,7414
explore_career_possibilities	0,7180	0,7187	0,7102	0,7278
improve_employability	0,7786	0,7879	0,7699	0,7824
develop_employability	0,7568	0,7584	0,7511	0,7602

Figure 11: AUC values for all the considered ML models

The least absolute shrinkage and selection operator (Lasso) classification (within the framework of *glmnet*) is selected since it shows the highest AUC value in most cases.

A common solution with a binary response is to use a logistic regression model:

$$p(\mathbf{x}) = P(Y = \text{T2B}|\mathbf{x}) = \frac{1}{1 + e^{-(\beta_0 + \mathbf{x}^T\boldsymbol{\beta})}} \tag{1}$$

where, $Y \in \{\text{T2B}, \text{Other}\}$ is the response variable and $\mathbf{x}$ is the matrix of predictors.

In the presence of a large number of potentially correlated predictors, we can use the Lasso penalization to improve the performances of the logistic regression model. Lasso regularization helps in preventing overfitting by penalizing the complexity of the model. Lasso indeed introduces a penalty term that can drive certain coefficients to exactly zero: a feature selection is therefore performed helping in identifying the most relevant predictors and removing irrelevant and redundant ones. Moreover, it can be effective in dealing with multicollinearity: through the process of penalizing certain coefficients to zero, Lasso tends to pick only one variable from a set of highly correlated predictors.

The logistic regression objective function with the Lasso penalty term is given by:

$$l(\beta_0, \boldsymbol{\beta}) = -\frac{1}{N}\sum_{i=1}^{N}[y_i \cdot \log(p_i) + (1 - y_i) \cdot \log(1 - p_i)] + \lambda \sum_{j=1}^{V} |\beta_j| \tag{2}$$

where the term $\lambda \sum_{j=1}^{V} | \beta_j |$ represents the penalization term defined as the sum

of the module of the model parameters. For the estimation of the parameters a weighted least squares iteration within a Newton step is then adopted (Friedman et al., 2010; Tibshirani et al., 2012).

4. Results and Discussion

In this section we show the results of application of machine learning models to understand the effect and impact of the drivers considered in Section 3.1 compared on the two KPIs under examination: perception of the current state of the labor market and student career planning.

The third to eighth columns of the figure represent a KPI and the values of the coefficient for each relevant driver in the model (see Equation 1).

4.1. Results: perceptions of the current state of the labor market

Figure 12 shows the results of the application of the machine learning model for the KPIs associated with perception of the current state of the labor market. Specifically, it displays the coefficients of application of the LASSO classification model.

	Driver	graduate opportunities	concern about competition	risk underqualified job	difficulty finding job	job uncertainty	job market uncertainty
General information	genderMale	0,26	-0,004			-0,42	-0,1
	age26-30				0,09		
	stage studyYear5				0,09		
Employability perception	skills importance	0,08					
	belief in obtaining job vs others	0,07	-0,37			-0,05	-0,04
	belief in obtaining job after graduation	0,41	-0,26	-0,2	-0,51	-0,37	-0,42
Career control	career responsibility	0,02		-0,06			
	career responsibility management	0,08			-0,09		
	career failure management				-0,02	-0,08	
	freedom in career choice				0,14		
	freedom in career choice^2			0,02	0,003		
	responsibility for career success failure	0,17					
Skills to be promoted by University	university reasoning ideationYes			-0,04			
Choice of university path	choice based on desire					0,05	
	good chances finding job	0,13		-0,07	-0,06		
Expectations	expectations for socially recognised career					0,13	
	expectations for enjoyable job			-0,04	-0,04		

Figure 12: Perceptions of the current state of the labor market: coefficients of the drivers in the model

4.2. Results: student career planning

Figure 13 shows the results of application of the machine learning model for the KPIs associated with student career planning. Again, it displays the coefficients of application of the LASSO classification model.

	Driver	planning future career	career future choices	explore career possibilities	improve employability	develop employability
General information	age26-30				0,07	0,03
	age31+				0,25	0,05
	stage studyYear5				0,12	
	student working status				-0,26	-0,05
Employability perception	skills importance		0,03		0,09	0,03
	belief in obtaining job vs others		0,11	0,04	0,15	0,07
	belief in obtaining job after graduation		0,05			
Career control	career responsibility		0,60	0,05	0,13	0,11
	career responsibility management				0,10	0,06
	career failure management		0,23	0,20	0,20	0,16
	freedom in career choice	0,14	0,09		0,23	0,12
	responsibility for career success failure		0,08			
Participation	participation career events	0,08	0,11	0,21	0,40	0,35
	participation student club				0,02	0,37
Choice of university path	choice based on desire	0,10	0,26	0,03	0,19	0,16
	choices based on experiences		0,04		0,02	
Expectations	expectations for active role society	0,04	0,05	0,07	0,11	0,12
	expectations for enjoyable job	0,08		0,10		
	expectations for enjoyable job^2		0,02			0,01

Figure 13: Student career planning: coefficients of the drivers in the model

4.3. Discussion and interpretation

4.3.1. Discussion and interpretation: perception of the current state of the labor market

Regarding perception of the current state of the labor market (Figure 12), the employability perception impacts especially on graduate opportunities, concern about competition and job/job market uncertainty. The career control variables have an impact especially on difficulty of finding a job and on the graduate opportunity while the choice of the university path have an impact on almost all the kpis except for the concern about the competition and the job market uncertainty. Finally expectations have an influence especially for the job uncertainty.

The findings in Figure 12 highlight two key aspects related to student labor market perceptions. On the one hand, some factors depend on individual skills and responsibility. On the other, some depend on external dimensions. Indeed, in relation to individual factors, students (above all males) have a high level of self-awareness because they consider skills development to be one of the conditions that guarantee them the opportunity to find a job. Furthermore, self-efficacy and internal locus of control allow them to consider themselves to be responsible for their own career success or failure. These factors are recognized by Fugate et al. (2004) as determinants of individuals' employability. Furthermore, belief in finding a job after graduation can be strongly linked to the field of study; indeed, engineering is recognized as a degree with better employment outcomes (Deloitte, 2018; Karmel, 2015), helping graduates obtain higher salaries and offering more favorable job prospects. The external dimensions with a generally negative impact are labor market competitiveness, the risk of being employed in a job for

which they are overqualified and job uncertainty, showing that students seem to be aware of competition in the world of work (Jackson and Tomlinson, 2020) and that students' self-perceived employability depends both on internal and external factors (Rothwell et al., 2008). Additionally, the negative effect observed with belief in finding job after graduation could call into question the value of academic qualifications for finding jobs (Tomlinson, 2008), and require students to improve their professional profile by participating in different activities to gain a positional advantage (Roulin and Bangerter, 2013).

4.3.2. Discussion and interpretation: student career planning

A brief glance at Figure 13 shows us the drivers with an important impact on the KPIs.

Specifically, employability perception has a moderate impact on future career choices as well as on the enhancement/development of employability. Career control drivers exhibit a high impact on future career choices and on improvement of employability while exhibits a moderate impact on both exploring career possibilities and improving employability. The participation to career events and students club impact in particular on improvement/development of the employabiliity while the choice of the university path has an impact especially on the career future choices and the improvement of employability. Finally, the expectations seem to have an influence on all the kpis considered and in particular on the improvement/development of the employability.

Other important aspects emerge from the student career planning findings (Figure 13). Students consider themselves to be the actors of their vocational path, capable of choosing and managing their own career, consistently with the previous results. This ability is an expression of students' self-regulation strategies, personal control and management of their vocational future (Coetzee and Stoltz, 2015). Each KPI analyzed within student career planning included four relevant factors with a positive impact: (i) expectations for enjoyable job - according to Hackman and Oldham (1980), if the characteristics of a job meet the jobholder's needs, they will be internally motivated and perform well. Although participants look for a job that makes them feel satisfied, the desire to play an active role in society could be connected to other factors; (ii) the need for social recognition and approval (Kim and Seo, 2014). Recognition plays an important role in constructing a career identity. Professional identity foresees a real negotiation between the educated and competent people and their environment through a process of socialization, made of constant exchanges with others, implementation of concrete

actions in different life contexts and situations. It is a developmental process that allows individuals to think about their professionalism, their position and social function (Damian, 2014); (iii) the expectation of playing an active role in society is connected to the desire to give back and contribute to society generating change in the world. It is a way to express human agency and self-efficacy that is related to the beliefs of people that events can be effectively managed through their choices and decisions; (iv) participation in career events or student clubs emerges as a dominant effect in all KPIs. Once more, students recognize the importance of developing positional advantage in order to stand out and increase employment possibilities. It mirrors student confidence and strong sense of control over their career.

The threats that participants seem to perceive in relation to labor market uncertainties and the risk of being employed in a job for which they are overqualified underline the responsibility of universities to care not only about students' employment readiness but also about their university-to-work transition paths. Indeed, students seem to have positive career planning prospects and skills but these may not be enough to navigate the complexity of the labor market. Universities must play an important role in supporting them in this transition process, teaching them how to evolve, and guaranteeing them authentic experiences and new teaching approaches that go beyond traditional and disciplinary methods (typical of each subject; they allow to maintain the control of knowledge in a field of study). In this sense, universities should become centers for the development of students' socio-professional identity (Grimaldi, 2016), where the aim is to guarantee authentic, real-life work experience-based learning strengthened by continuous business-university dialogue, to explicitly enhance students' adaptability and proactivity when facing labor market challenges. Positive career planning prospects do not guarantee a successful university-to-work transition. Facilitating students' proactive engagement with career development in real employment contexts helps them better define their own career profiles, identify resources, such as networking, exposes them to real problem solving, and introduces them to communities where they can test their knowledge, skills, and resilience.

5. Conclusion

This study analysed the engineering student labor market and career planning perceptions giving useful insight about how to enhance employability among engineering students. In particular, the survey investigated some important dimensions namely, perceived labor market conditions, self-perceived employability, ca-

reer control and planning, proactivity, and developing positional advantage. Such information are particularly important for universities for two main reasons: a) higher education institutions (HEIs) can engage students in a university-business dialogue to understand to what extent students' perceptions reflect the real labor market conditions and opportunities; b) the development of a university-business dialogue can support the analysis of labor market expectations and universities' contributions in the development of students' capabilities and skills considered crucial for students' employability. The challenge of our data analysis consist on extracting information about the factors that influence both student perceptions of the labor market and their career planning, especially to provide valuable insights to various stakeholders, namely students, universities and employers. With this aim data analysis was carried out through the application of machine learning model. Findings offer relevant implications for career development learning in HEIs and graduates' university-to-labor market transition paths. According to this new and complex employability scenario, the mission of universities changes, not only in terms of promoting the knowledge and skills needed to gain and maintain a specific job, but also in terms of developing those skills that allow students to move competently through uncertain contexts, and learn how to design or redesign their professional life. Indeed, findings showed that students consider it important to develop a positional advantage in order to better develop a skillful profile. The engineering students in this study seem to perceive themselves to be well-prepared with good potentiality for finding a job thanks to their knowledge and skills and because their field of study offers them many more job opportunities than others. One of the most relevant insights that these findings offer is the definition of a significant picture of the HEIs as systems responsible to act their role according to a general social perspective. Today, promoting knowledge do not mean only to providing students with skills and abilities, but creating learning environments where the construction of knowledge is strongly connected to the external world and the social issues. Why are females still facing challenges connected to the idea of finding positions within some fields (e.g. Engineering, as in this study)? The themes of gender issues, weak university-labor market partnerships, are useful to promote fruitful relationships, innovation in teaching methods and curriculum, and in workplace contexts as well; the impact of personal beliefs on career development and career choices, need to be included in the agenda of an entrepreneurial university with social responsibility. This contributes to provide HEIs with the opportunity to fulfill their third mission for economic and social development. Further studies could consider subsamples of students from differ-

ent backgrounds to understand if there are differences in perceptions of the labor market and career planning and how the educational offer should be adapted in terms of skills promoted and capabilities developed for different students' background. They could also investigate the social and entrepreneurial character of universities.

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