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INTEGRATING INDUSTRY 4.0 IN ENGINEERING EDUCATION

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The paper analyses both the importance of introducing Industry 4.0-related courses into the curricula of Industrial Engineering and Management (IEM) education and the appropriate ways to do so. The case study focuses on questioning two categories of relevant stakeholders: students and professors. It also analyses their position on the introduction of new courses tailored to Industry 4.0 content and/or the integration of Industry 4.0 elements into existing courses.

1. INTRODUCTION

Automation combined with the introduction of artificial intelligence and the internet of everything (including internet of things, internet of data, internet of people, and internet of services) [1] in industrial processes, especially in manufacturing, has intensified and has been labelled by some authors as Industry 4.0 or the 4th industrial revolution [2]. Reducing the costs through automation and machine learning [3] is applied in a diverse range, from automating manufacturing processes to automating software deployment [4]. Industry 4.0 has had a strong educational impact and has brought a consistent presence of different concepts related to Education 4.0 in scientific papers [5, 6].

The potential of Industry 4.0 for Industrial Engineering and Management Education has been proven to be consistent from the point of view of two major stakeholders: the professors and the students, with both sides engaged in the teaching-learning process and taking its complexity into account [7]. Different types of Industry 4.0 content useful for Industrial Engineering and Management education have been identified in the literature. Thus, the paper continues previous research by assessing the importance of Industry 4.0 from the point of view of both students and professors identified as the most important stakeholder groups, as well as searching for the different types of enhancing existing curricula based on Industry 4.0 contents. The central question of the paper is: which is the most adequate form for universities to introduce the needed industry 4.0 related components in Industrial Engineering and Management curricula?

2. METHODOLOGY

The paper has exploratory objectives and, therefore, is based on qualitative research methods suitable for this context [8].

To align with exploratory objectives, the paper uses a recommended method - the case study [9]. The case study method relies on both observation and survey [10]. The case study about possible forms of introducing industry 4.0 related elements in Industrial Engineering and Management (IEM) Education is based on two surveys with the most relevant stakeholders: the students and the professors, as is recommended in another research project related to the field [7].

To gain visibility, the research project was supported by two highly relevant European academic organizations: the European Students of Industrial Engineering and Management (ESTIEM) and the European Professors of Industrial Engineering and Management (EPIEM).

The sample for the students' survey comprises 262 students from 17 countries (Austria, Bulgaria, Belgium, Croatia, Finland, France, Germany, Greece, Italy, the Netherlands, Norway, Poland, Portugal, Romania, Serbia, Spain, Turkey) who answered a broader, multithemed survey. From this sample, only 134 answered the Industry 4.0-related questions.

The sample for the professors' survey contains 41 professors from seven countries (Austria, France, Germany, Italy, Portugal, Romania, Serbia) answering a wider multithemed survey. From this sample, 27 answered the Industry 4.0-related questions.

The questions answered by the respondents were:

- Do you think that Industry 4.0-related courses would be a good improvement to your curricula?
  Possible answers:
  - Yes
  - No
  - I don't know the concept of Industry 4.0, and therefore, I have no opinion about this subject.
- How important would the addition of Industry 4.0-related elements be in your curricula?
  Possible answers on a scale from 1 = lowest importance to 10 = highest importance.
- Which ways of integrating Industry 4.0 elements do you think would work well within your study program in order to increase your benefits?
  Possible answers:
  - New courses shaped specially for Industry 4.0-specific content
  - Integration of Industry 4.0 elements in existing courses
  - None of the above-mentioned, integrating Industry 4.0, would be a bad idea.

For the respondents answering the first question with "I don't know the concept of Industry 4.0, and therefore I have no opinion about this subject," the research team decided to ignore the subsequent answers to more detailed questions, as answers without any knowledge have a great chance of being irrelevant and thus contaminating the results. They could lead to conclusions that are based on answers given by people without Industry 4.0-related knowledge.

The last question allowed the respondents to give multiple answers, either considering both approaches of new courses related to Industry 4.0 and the integration of such content in existing courses as being adequate or favoring one of them over the other.

The statistical analysis of the responses is based on simple univariate methods, showing the distribution of responses on the specific scale for each Item. The graphical representation has been chosen adequate to the nature of represented results: either a pie, in the case of single choice answers with a number of different answer choices small enough to allow a transparent overview through a pie chart, or in cases of multiple answer choices, where each percentage is independent and the sum is thus not 100% a two dimensional

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horizontal bar chart. These choices enable the reader to have a fast overview of the results, being also able to visually compare the results of the two stakeholder groups: the students and the professors, for each analyzed item.

3. LITERATURE REVIEW

The literature is showcasing a lot of potential changes regarding education, fueled by the perceived strong innovation wave of Industry 4.0 [11]. Some point to the potential of new learning media, *e.g.*, pointing out the potential of e-learning solutions [12], while others aim to find solutions to answer different learning styles [13]. Teachers and students have access to a wider pool of electronic devices, and they are supported by AI portals, which can lead to some main advantages [14]:

- 7hey are independent in terms of space,
- they are independent in terms of time,
- and they can adapt to their own learning pace.

Even before the pandemic, the quality of web-based solutions was praised [15], with a special focus on visual learning and enhanced options for visualization modelling [16, 17]. Virtual laboratories represent one of these solutions, bringing the advantages of investing less time and financial resources [18]. Integrating robots into education and programming them to do certain tasks can be an excellent motivator for students [19]. These trends in online teaching were then totally embraced by universities during the pandemic [7].

Another major element is gamification, being supported by many authors [20–22] as serious games are excellent ways to develop competencies in a wide area of educational domains ranging from defense education [23] to business and industry [24,25] with a special focus on entrepreneurship [26,27] and its suitability for industrial engineering and management [28,29]. Gamification is highly relevant, as studies of experiencing such serious games in engineering education, proved that 21 different relevant competencies were developed by the participating students: analytic thinking, strategic thinking, decision making, team work, defining goals, opportunity recognition, problem recognition, problem solving, intuitive thinking, proactive thinking, communication, time management, responsibility, courage, argumentation, self-esteem, conflict management, creativity flexibility, diplomacy and delegation [29]. Most of these competencies, more exactly the first 17 mentioned above, have been reported by at least 50% of participating students to be developed in a substantial or outstanding manner during one semester of experiencing the General Management business simulation [29]. Even the last 4 competencies had good results, as creativity and flexibility fell short of the 50% threshold, being reported by 49% to increase with a substantial or outstanding development, while diplomacy had 47% and delegation 42% of respondents regarding the competence development at a substantial or outstanding level [29]. The merit of such educational innovations is underlined by the fact that most of these competencies belong to the category of social competencies, which is strongly appreciated by the employers of young engineering graduates, as [30] point out in a study that 65.75% of questioned engineering graduates perceived that social competencies to play a very important role the their workplace, ranking 1st before professional competencies regarded as very important by 53.42% and methodological competencies considered very important by 49.32% of the respondents. In another research, the importance of these competencies was confirmed: 95,71% of respondents considered problem solving to have a positive importance, similar importance but acknowledged by a smaller percentage of 81.43% was registered for decision making, or time management acknowledged by 77.46%, argumentation by 70.59%, and conflict management by 70& of the respondents [31].

These social competencies, often underestimated in engineering education, are extremely important in communication processes at the workplace, technical communication being associated with specific requirements as a professional language [32] and coming with specific language-related communication challenges for engineers [33].

A special role related to the potential changes of the education landscape is related to the use of Industry 4.0 learning environments [34] and the introduction of both contents and methods related to Industry 4.0 in the curricula of Industrial Engineering and Management programs [7]. These potential changes mirror the way Industry 4.0 evolves regarding its main components:

- mechanical innovations
- software innovations,
- organizational and management approaches,
- organizational culture [35].

There are specific Industry 4.0-related contents that have been identified as relevant to Industrial Engineering and Management education:

There is a strong need for engineers with a good understanding of digital business models that combine improved customer access and interaction with complete services [36] as well as digital methods included in Enterprise Resource Planning systems that optimize production, information, labor capacity, and defect management [37].

Industry 4.0 solutions can lead to cost-effective production flexibility, which is of utter importance in the industry, *e.g.*, in automotive [38]. Robotics and the integration of robots in education are acknowledged as being of great advantage for the development of engineering competencies and for the motivation of students [19].

The importance of adding management and organizational culture elements next to hardware and software-related Industry 4.0 contents is not completely new and was emphasized in previous research, with the condition that the level of expertise in the universities is adequate or is enhanced to the desired level through training courses [7]. The way people act in an organization based on assumptions, attitudes, beliefs, norms, and values is the reflection of the enterprise culture [39]. It is a central factor for success [40], and it has the potential of transforming the employees of an enterprise into a community with shared mission and vision as well as underlying values [41,42].

Learning by doing, combined with skills in "advanced analytics, Internet of Things and digital security" [43], is essential for preparing students for future challenges related to Industry 4.0, thus providers of education services like universities have a need for emerging technologies [7]. The offer of personalized content in an interactive frame in the field of Industrial Engineering and Management is enhancing the competitiveness of graduates in a strong manner in the labor market [44].

4. CASE STUDY

The question at the center of this Europe-wide case study is: which is the best way of integrating identified useful Industry 4.0-related content, ranging from various technical elements, including software and hardware, to management elements [7] in IEM education.

The starting point is, of course, the question of whether integrating such elements is considered useful. The starting question "Do you think that Industry 4.0 related courses would be a good improvement to your curricula?" from the research among European students shows that from 134 respondents, 88 (66%) considered Industry 4.0 related courses to be a good improvement for their curriculum (Answer Yes). At the opposite pole, only 2 (1%) respondents gave a negative answer (Answer No). The rest of the sample, namely 44 students (33%) chose the option "I don't know the concept Industry 4.0, and therefore I have no opinion about this subject". The results regarding the importance of Industry 4.0-related courses for the students are visualized in Fig. 1.

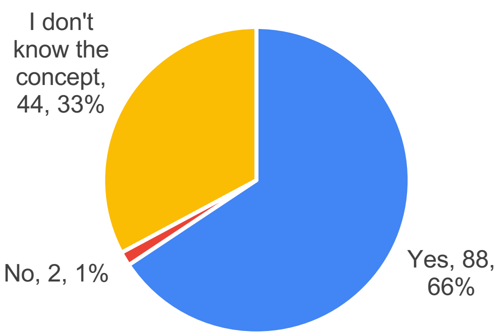

Fig. 1 – Are Industry 4.0-related courses a good improvement for the curricula perceived by the students?
N=134 respondents.

The large majority favoring the addition of Industry 4.0 elements among European students, with 88 students (66%) versus only 2 students denying its worth as a good improvement, is encouraging for proceeding with the research regarding the best ways to integrate such content. However, the fact that a large minority of students, 44 (33% of the sample), are not informed enough to have a clear opinion on this question indicates further research potential regarding the need to have informed students, and appropriate ways of achieving the goal of having well-informed students.

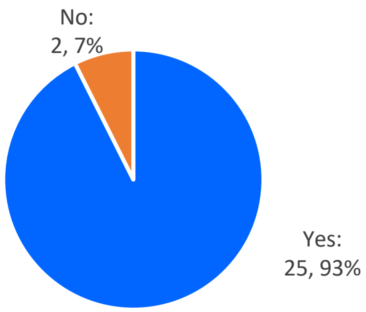

Fig. 2 – Are Industry 4.0-related courses a good improvement for the curricula perceived by the professors?
N=27 respondents.

In the survey with the professors, the uninformed group is totally missing, which is in line with the fact that the professors' group is naturally very informed about relevant developments in the industries relevant to engineering education. The findings indicate that a high majority of 25 (92.6%) consider Industry 4.0-related courses to be a good improvement for the Industrial Engineering and Management curricula, while only 2 (7.4%) deny its importance and answered No. This shows an even stronger support for Industry 4.0-related courses among the second stakeholder group – the professors, as we can see in the graphical distribution of answers in the following figure (Fig. 2):

A yes-or-no question, like the starting question, is a good start for research, but it does not provide any information about the magnitude of perceived importance, so a follow-up is needed.

To assess the quantitative importance of Industry 4.0-related courses, respondents rated the importance of Industry 4.0-related elements on a scale from 1 to 10.

The findings show that the average importance value for Industry 4.0-related elements is 8.07 on a scale from 1 to 10, where 93% of the respondents rated it between 6 and 10, and only 7% gave a rating in the lower half of the scale between 1 and 5.

The complete distribution of importance ratings between a minimum of 1 and a maximum of 10 are shown in the following figure (Fig. 3), where we notice that none of the respondents graded the importance as 1, 2 or 3 in total opposition with a very good percentage of the students' stakeholder group which allocated an importance of 10 (33%), 9 (17%) or 8 (24%), these best ratings summing up 74% of the hole stakeholder group.

The fact that a 3rd - 33% of the students answered with the maximal importance rating of 10, heavily underlines the magnitude of the perceived importance of Industry 4.0 elements for IEM students.

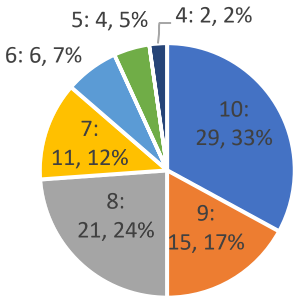

Fig. 3 –Students' perception of the significance of including Industry 4.0-related elements in the curricula on a scale from 1 (min) to 10 (max).
N = 88 relevant respondents.

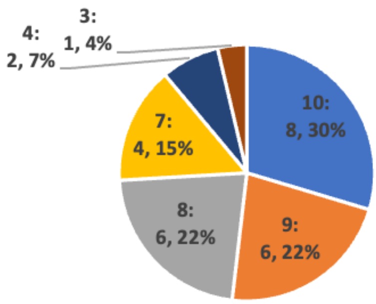

Fig. 4 – Professors' perception of the significance of including Industry 4.0-related elements in the curricula on a scale from 1 (min) to 10 (max).
N = 27 respondents.

The responses in the professors' sample converged with the answers of the students: 24 (89%) of the 27 respondents credited the importance in the upper part of the scale between 7 and 10, while only 3 (11%) assessed it in the lower half of the scale. The maximal importance rating of 10 was the choice for 8 (30%) of the respondents. A better visualization of the importance of adding Industry 4.0-related elements in the curricula is presented in Fig. 4.

The integration of Industry 4.0-related elements offers two options: either adding new courses tailored to Industry 4.0 to the curricula or integrating these elements into existing courses.

Out of 117 IEM students answering this question in a relevant manner, 84 (72%) supported the Integration of Industry 4.0 elements in already functioning courses, while 68 of them (58%) supported the introduction of new courses with Industry 4.0-specific content. The two options have 35 students (30%), so almost a third of the respondents support both. Figure 5 below presents a good visualization of these findings:

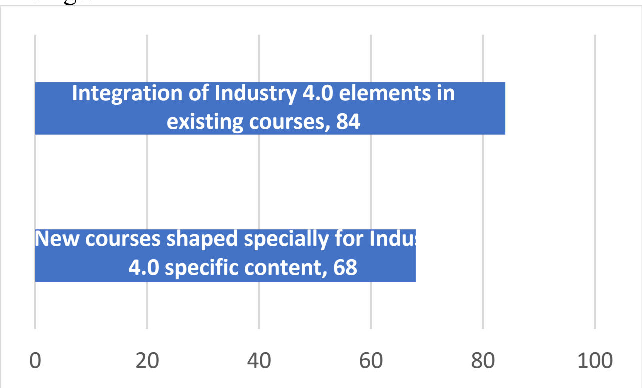

Fig. 5 –The adequate way of introducing Industry 4.0-related elements in the curricula perceived by the students.
N = 117 respondents.

The professors' sample converges with an even stronger support for the integration of Industry 4.0 elements in already functioning courses by 23 (88%) out of 26 professors, while the introduction of new Industry 4.0 courses is supported by 11 (42%) professors. In this group, we have 8 professors supporting both alternatives, the percentage – 30% is the same as in the students' sample. The corresponding figure is Figure 6, which shows the data distribution:

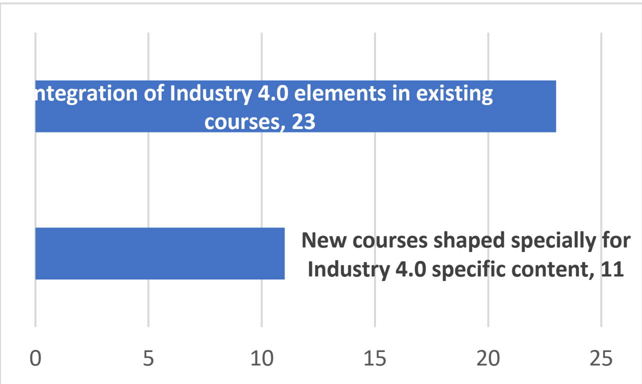

Fig. 6 –The adequate way of introducing Industry 4.0-related elements in the curricula perceived by the professors.
N = 26 respondents.

5. CONCLUSIONS

As a conclusion, we can observe that both IEM stakeholder groups, the students, as well as the professors, think that the Industry 4.0-related contents represent a good improvement for Industrial Engineering and Management curricula.

Regarding the way to do it, we see a higher support for integrating Industry 4.0 elements in existing courses in the answers of both stakeholder groups, as the opinions of students and those of professors converge regarding this matter.

This strategy, which is also easier to implement in universities, as in this case, there is no need to change the structure of the curricula. Being aware that in some cases the integration of Industry 4.0 elements in already functioning courses is not possible, both groups also support the introduction of new Industry 4.0 courses.

The two strategies can be combined to keep IEM studies in line with industry evolution and to prepare students for a good insertion into the labor market after graduation.

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CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Ioana Mustață: concept, methodology, research, wrote the main paper draft.
Iosif Vasile Nemoianu: methodology, writing, validation, review.
Radu Mircea Ciuceanu: methodology, writing, validation, review.
Ioan-Cristian Mustață: concept, research, and surveys, writing.

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