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Interdisciplinary Teaching Activities for High School Integrated to Vocational Education Promoting Reflections on Industry 4.0 Technologies and Their Implication in Society

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Abstract: The educational system in Brazil, especially the high school level, is characterized by a division, offering a general and humanist formation for the economic elite, and direct preparation for labor, for the working-class. Aiming to overcome this duality and contribute to the polytechnic formation of vocational education students, this paper presents and analyzes interdisciplinary teaching activities that discuss the relationships between Industry 4.0 technologies, production systems, and education. The educational product, developed and applied based on the action research methodology, consisted of identifying the students' prior knowledge, three units of teaching activities, and a final evaluation questionnaire. According to the students' background and their suggestions, the content and didact methodology of each unit was selected, including the history of industrial revolutions, technologies arising from Industry 4.0 (internet of things, data mining, and cloud computing), the challenges of the fourth Industrial Revolution on the economy and labor. Didact methodologies include dialogic lecture based on slides, hands-on practical activity experimenting Industry 4.0 technologies through free online applications, and debate. Interdisciplinary activities were developed at the Federal Institute of Education, Science and Technology of São Paulo, involving students of the 4th year (last) of high school integrated into vocational education with a qualification in Industrial Automation. During the application it was observed that the use of educational product led to considerable levels of motivation and promoted reflections related to the impact of the industry 4,0 technologies in society and employment. Also, it has been verified that the didact sequence increases the student capacity to identify problems and propose possible solutions; understand labor different dimensions (technology, employment, politics, and economics); use strong argumentation based on reliable sources, proposing possible interventions. Thus, the interdisciplinary approach of technological development, considering not only the technical concepts but also the historical and sociological issues related to the application of technologies in the productive system, contributes to a critical teaching-learning process and the omni-lateral formation in vocational education.

Keywords: Access to education and training, Polytechnic, VET for secondary students, Education industry relationship, Industry restructuring, Industry 4.0, Society

1. Introduction

Historically, the educational system is constituted by a division with economic and social origin: a general and humanist formation for the elite and direct preparation for labour for the working class. The structure of this division in education takes different forms throughout history, according to changes in the productive system, always preserving the interests of the economically dominant class and contributing to the intergenerational transmission of social and economic status (Bowles & Gintis, 1976).

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For over a century there have been proposals with the intention to break this structure, offering to the working-class "… an education that will, in the case of every child over a given age, combine productive labour with instruction and gymnastics, not only as one of the methods of adding to the efficiency of production, but as the only method of producing fully developed human beings" Marx (2015). For decades there have been studies that seek, in one way or another, to contribute to this overcoming. In Brazil, Vocational Education is offered from secondary education, in this level called technical education, in two categories: Technical Certificate or Technical Certificate Integrated to Regular High School, in which the vocational preparation occurs simultaneously with the regular secondary or high school. Among the institutions that offer technical education stands out the Federal Institutes of Education, Science and Technology (IFs) (Tomasi et al., 2015). The Federal Institute of São Paulo (IFSP), campus Sertãozinho, offers two technical courses integrated into regular high school: Chemistry and Industrial Automation. The Industrial Automation integrated high school course includes discussions about current industry, but generally just about technical issues, without stimulating students to critical reflection on the changes caused by technological evolution in social and labour relations. This broader understanding is essential so that integrated technical education contributes to the full development of the students in the perspective of an integral, omni-lateral formation, that is based on work as an education principle (Frigotto et al., 2009).

This paper aims to investigate, develop and analyse the students' conception of the impacts of Industry 4.0 in the world of work, stimulating reflections and discussions on the subject. Thus, a proposal of teaching activities for an interdisciplinary approach to Industry 4.0 technologies and their implications for society is presented, including the process of elaboration and development of didactic activities. Results were analysed and the educational product developed may contribute to the motivation and learning of high school students concerning its intellectual, physical, social, emotional, and cultural dimensions. This paper is divided as follows: Section 2 presents a theoretical framework about the conceptual bases of Professional and Technological Education, Industry 4.0 technologies, and their impacts in society; in section 3, we briefly revise the most relevant topics regarding the methodology based on action research fundamentals, including a description of didactic activities elaboration and application, and the methods of data collection and analysis; following, in section 4, we detail the steps of the didactic activities - the Educational Product; the obtained results, from the diagnostic phase to the final stage of application are presented and discussed in section 5, and, finally, we draw the conclusions in section 6.

2. Theoretical Framework

2.1 Vocational Education

As a very illustrative example of the dualist school theory of Bandelot and Establet (Saviani, 2019), secondary education in Brazil is characterised by a structural duality that remains throughout history: on one side, a general and intellectual preparation aiming at university access, for the more favoured economic classes; on the other hand, a practical and professional training, preparing direct for labour, for the working-class youth (Kuenzer, 2000). For some time now, and more intensely in recent decades, there have been discussions in the academic literature about overcoming this duality based on the proposal of polytechnic formation. The idea of polytechnic education was firstly elaborated by Nadezhda Krupskaya, based on Marx´s classics, and its aim to introduce students to the foundations of modern engineering in connection with the principles of natural science and with the organisation of labour and the life in society (Skatkin & Cov'janov, 1994). Marx's initial proposal was that the education of the working class should include Mental Education, Physical Education, and Technological training (Marx, 2015), and in this sense, he "is pointing to the integral education of the human being, that is to say, an omnilateral education" (Moura et al., 2015). The principles of omnilateral, polytechnic, or integral education do not support the specific professionalisation of adolescents. Despite this, the condition of the working class in Brazil is critical, and because of the large socio-economic inequality, many young people (before the age of 18) seek entrance into the world of labour with very low schooling and no professional qualification (Moura et al., 2015). To respond to this reality, "Professional and Technological Education" emerges, including two categories: technical secondary education and technological tertiary education (Tomasi et al., 2015).

In technical secondary education or vocational education, the students can pursue the vocational qualification simultaneously/integrate into their regular secondary education (Tomasi et al., 2015). It is considered that these courses, that offers a general formation in natural and social science, letters, philosophy, art, and physical education, integrated with specific professional qualification, are the possible path so that, in the future, be possible to implement the proposed omnilateral, polytechnic, integral education (Moura et al., 2015). The Federal Institutes of Education, Science and Technology (IFs) are specially dedicated to providing "Professional and Technological Education". Created by law n.11.892, of December 2008, have as one of its purposes to promote the integration of regular to vocational education. The Federal Institute of São Paulo (IFSP) campus Sertãozinho has two vocational courses integrated into high school, with qualifications in Chemistry and Industrial Automation. Both courses are related to the industry, but the Automation course is more directly related to electronic and computational applications in the production processes.

2.2 Construction of References

The term Industry 4.0 was first introduced in 2011 by a group of representatives from different segments and supported by the German government as an initiative for technological advances, innovation, and competitiveness in the German manufacturing industry (Oztemel & Gursev, 2020). Thus, factories would be encouraged to adopt new technologies which would improve the approaches of their manufacturing processes and become "smart factories". Furthermore, production systems with these different technologies would become vertically integrated with business processes, so market demands could be quickly accomplished. Some technologies have been developed and applied in the industry to achieve these goals. These technologies are often known as the pillars of Industry 4.0. Among them, the Internet of Things (IoT), artificial intelligence algorithms for data mining, cloud computing, additive manufacturing using 3D printers, augmented reality, among others could be highlighted.

Aiming to develop learning in vocational education students, this work focusses on some of the technologies, which are: Internet of things, Data mining, and Cloud computing, as they could be used in a wide range of applications, both in the industrial and domestic areas, as well as in the education, commerce, among others, providing students a reflection on their reality, motivation, and interest. The advent of Industry 4.0 represents an opportunity for enterprises to improve their manufacturing processes, based on technologies such as artificial intelligence algorithms, the Internet of Things (IoT), and cloud computing (Dias et al., 2021). These technologies aim to improve the operational efficiency of industries which could imply deep modifications in work relationships and production activities.

2.2.1 Internet of Things

The technology known as the Internet of things (IoT) provides a connection of any object to the Internet so that they can exchange data. These objects could be industrial equipment as well as an automobile or household device. These "things" that communicate using internet infrastructure can self-configure and operate with no human intervention (Gaikwad et al., 2015). Typically, sensors and/or actuators are connected to these objects. Sensors are able to collect data from the industrial process or domestic environment and make them available via the internet, and through cloud computing tools. They can store data or even make decisions acting on the system using objects connected with actuators. These devices may also be able to process these signals and make decisions automatically.

Sensors and devices capable of connecting to the internet are getting cheaper, increasing exponentially the number of IoT devices. To enable data exchange on the internet, each object needs an IP address. The Internet Protocol version 6 (IPv6) allows IP addresses in the order of 2^{128} addresses, enabling the tremendous number of "things" connected to the internet. When it comes to the industrial area, the Internet of Things provides communication between machines in a production process, generating less need for human intervention in manufacturing environments (Oztemel & Gursev, 2020). In this way, production systems with IoT technology are interconnected through the internet, generating an effective work environment in a more optimised way.

2.2.2 Data Mining

Automatic learning algorithms can be trained from a large amount of data, being able to recognise patterns or make predictions. In this context, the term data mining can be defined as the process of discovering patterns in a large universe of data (known as big data) that could extract relevant information, providing advantages, usually economic advantages, in the application of certain actions, such as in the case of industrial production processes (Witten & Frank, 2015). Using artificial intelligence algorithms, it is possible to solve problems based on the analysis of collected and processed data, involving multidisciplinary resources such as statistical tools, optimisation, intelligent systems for pattern recognition, among others. Artificial intelligence algorithms for data mining could be implemented as presented by Awad and Khanna (2015):

i. Collect the data: Selecting a set of data that can be useful for solving the problem.
ii. Pre-process the data: Present the data in a way that is understandable.
iii. Transform the data: Transform the data for use in the algorithm and to learn the problem behaviour.
iv. Train the algorithm: Select training and testing sets from the transformed data. The training set is used in the algorithm learning process, extracting information from the system behaviour.
v. Test the algorithm: The algorithm performance is evaluated using the testing set.
vi. Apply reinforcement learning employs dynamic performance rebalancing to learn from the consequences of interactions with the environment.
vii. Execute the algorithm: Apply the validated model to perform an actual task of prediction.

Some tasks that can be performed by these algorithms are pattern recognition, such as medical diagnostics, email filtering, computer vision, voice recognition, computer virus detection, malicious attacks; problem-solving and process control: control of a mobile robot, driving vehicles, playing video games, solving maths problems, among others; forecasting time series: weather forecasting, machine failures, among many other tasks.

2.2.3 Cloud Computing

Cloud Computing services are employed to host and manage servers, either for the internal use of the industry itself or to connect the products on the market (Kushida & Pingali, 2014). The main advantages of these services are the automatic availability of computational resources according to the need of the task, transparent measurement services to the user, providing conditions for the user to monitor and control the computational resources consumed and financial costs, data security, and greater availability of the system. Additionally, cloud services offer tools to access functions, such as data mining algorithms for big data processing, cognitive functions for speech, text, and image processing, among many others

In this way, a common scenario in Industry 4.0 is the data collected by the various sensors installed on the IoT devices that can provide this information to the cloud servers, which also could collect market and logistics information, among others. Thus, cloud computing services for storage, keep a large amount of data (big data). Other cloud computing services can apply data mining algorithms and be able to extract useful information from the collected data, providing improvements and advantages to the industrial production processes, or even to companies from other segments. The main advantages of using cloud computing services are:

i. Cost reduction: Siepermann et al. (2016) show that cost reduction is a decisive factor in a company's decision to migrate from its own localhost to a cloud computing service. A system with its own local computational services has a high cost since it requires a physical space, system maintenance expenses, electricity, adequate electrical network, adequate refrigeration system, and, in addition, requires its own technical team.
ii. Elasticity: Armbrust et al. (2010) cite elasticity provided by cloud computing as the main advantage. In proprietary Information Technology systems, equipment must be sized to meet peaks in processing and usage, while a cloud computing system can automatically adjust its processing capacity, based on real-time usage measurements, increasing its capacity in resource demand peaks and reducing it in low demand.
iii. Reliability: Gajbhiye and Shrivastva (2014) indicate reliability to keep the services running without any interruption. Cloud computing services currently offer reliability close to 100%, as they use a technical team to guarantee the uninterrupted operation of servers, offering hardware redundancy, and uninterruptible power supplies.
iv. Security: According to Siepermann et al. (2016), data-related risks in the use of cloud computing services are lower compared to the company's own server hosting. Cloud computing services are common targets of cyber-attacks; however, they have the capacity and equipment capable of identifying and blocking these attacks before they can pose a risk to the data.

Despite all these technologies, Oztemel and Gursev (2020) show that there is a failure in using a systematic approach to make the necessary assessments for those who intend to implement these technologies in their real applications. Scientific research focuses on understanding and defining concepts and developing systems, business models, and methodologies related to technologies; and industries tend to shift from industrial machines and intelligent products as well as potential customers of these developments. However, it is estimated that Industry 4.0 technologies will have a huge effect on society (Oztemel & Gursev, 2020). Therefore, it seems that there is a gap in relation to encouraging reflections by professionals and future professionals on the impacts these technologies would bring to society and the labour market.

2.3 Industry 4.0 Impacts on the Society

Technological development over time has provided significant advances in various sectors, such as food, transport, health, quality of life, social relations, and work. According to Schwab and Forum (2016), every revolution brings benefits and challenges to the socio-economic status of countries involved in this transformation, and industry 4.0 is no exception. There are manifestations of quite antagonistic views regarding the benefits and challenges of this process, especially in work relations. Structural unemployment is a social phenomenon produced by situations such as the imposition of the interests of hegemonic capital centres on other nations, and the incorporation of new technologies and organisational strategies, thus increasing productivity and decreasing the number of workers. In addition, this approach has been destroying the environment. What was previously performed by technology as routine tasks in industries has been efficiently executed through artificial intelligence and Big Data in almost all sectors, based on pattern recognition and prediction algorithms with digital solutions.

With IoT, people are becoming more and more connected to devices, and those devices are increasingly becoming connected to their bodies, which could increase positive health outcomes. Still, they could decrease people's privacy and data security. With the increased computing power and falling of hardware prices, it is possible to connect anything to the internet, enabling greater communication and new data-driven services based on increased analytic capabilities, which could imply in improved quality of life, rise in productivity, and more transparency of processes in general, however, it could promote job losses for unskilled labour and stimulated hacking and cybersecurity threats (WORLD ECONOMIC FORUM, 2015).

Data mining algorithms and big data will enable better and faster decision-making in a wide range of industries and applications. Automated decision-making can reduce complexities for citizens and enable businesses and governments to provide real-time services and support for everything from customer interactions to automated tax filings and payments> However, leveraging big data to replace processes that today are done manually may render certain jobs obsolete (WORLD ECONOMIC FORUM, 2015). According to Graglia and Lazzareschi (2018), as the role of humans is increasingly reduced to mere supervision of automated processes, it is difficult for employees to develop competence to operate them, critically analyse, and even improve them. Unlike similar historical movements, the new digital revolution would strongly impact low-income and less-skilled occupations due to its technological characteristics" (Graglia & Lazzareschi, 2018). Thus, jobs requiring higher qualifications have a lower risk of replacement and a possible increase in demand.

To sum up, it seems that technologies of Industry 4.0 could shift the labour markets and skills, promoting unemployment of unskilled jobs, but could create new jobs and opportunities that currently do not exist. Finally, it is noteworthy that higher education integrated into vocational education could contribute to the possibility of building a proposal for the integration of general and specific knowledge, which includes basic and professional training. Thus, students become able to understand reality, being critical citizens.

3. Methodology

The research process was organised based on the action research methodology (Tripp, 1994). The action research cycle was composed by:

i. **Planning of** a changes to practice and the process of results evaluation.
ii. **Implementation of** the change to practice and the production and preliminary analysis of data.
iii. **Evaluation of** the change to practice and the action inquiry process based on collected data (Tripp, 1994).

Table 1 shows how the planning, application and evaluation of the proposed educational product was related to action research cycle.

Table 1 - Representation of action research cycle for the educational product proposed

Action Sequence	Practice	Inquiry
Planning of	Literature reviewing Identification of student´s background (conversation round and questionnaire) Elaboration of lesson plans	Preparation of answers for conversation circles and questionnaire Preparation of tasks to be performed by students during activities
Implementation of	Development of teaching activities about History of industrial revolutions, Industry 4.0 technologies and Economic, social and employment challenges of Industry 4.0.	Record of researcher's observation during the application of teaching activities. Materials produced by students
Evaluation of	Final questionnaire application	Data analysis: students' participation, products, and questionnaires

The entire research process represents an action research cycle. In addition, each interdisciplinary teaching activity was developed according to a cycle since results from each activity (evaluation of) provide the starting point (planning of) for further improvement in the next cycle. The proposed product was structured and developed at the Federal Institute of Education, Science and Technology of São Paulo (IFSP) Campus Sertãozinho. The participants were forty students in the 4th year (last) of high school integrated into vocational education, with a qualification in Industrial Automation. These participants chose due to the intrinsic relationship between the proposed educational product and the pedagogical plan of the industrial automation course. Both aim to approximate the experiences of primary and professional education. Thus, the development of this project could contribute to the professional in the field of industrial automation, training for a wide understanding of scientific and technical content intertwined with the impacts of new technologies arising from the fourth industrial revolution in the society. Each stage is detailed in the following subsections.

3.1. Planning

A literature review was held concerning the main conceptual bases and publications about vocational education, teaching and learning methodologies, and Industry 4.0 technologies. The aim of the review was to substantiate: the understanding of industry technologies' evolution from different perspectives, the planning of effective improvements in teaching practices, and the analysis of results obtained with the educational product application. The databases used were Web of Science and SCOPUS. The terms employed were: "Professional and Technological Education", "Fourth Industrial Revolution" and "Industry 4.0". It is essential to highlight that when considering the syntax "FOURTH INDUSTRIAL

REVOLUTION" OR "INDUSTRY 4.0" more 17.000 publications in Web of Science and more than 23.000 publications in SCOPUS were achieved. However, when considering the syntax "PROFESSIONAL AND TECHNOLOGICAL EDUCATION" AND ("FOURTH INDUSTRIAL REVOLUTION" OR "INDUSTRY 4.0"), only one publication was achieved in Web of Science, and none in SCOPUS database. Thus, there is an indication that the industry 4.0 theme in vocational and technological education is a gap in the scientific community.

For the identification of students' prior knowledge, a conversation strategy was used, observing the construction of questions, concerns, doubts, and interests related to the theme. The conversation was conducted online using Microsoft Teams software for thirty minutes. Initially, the research project was presented, and some questions were discussed together with the students. The guiding questions were:

i. Have you ever heard about the term Industry 4.0?
ii. Do you think these technologies could change society and work as we live today? Would it be positive or negative?
iii. Did previous industrial revolutions interfere in society?
iv. Does anyone have any examples of how some technology has changed society and work?

In addition, also to verify the prior knowledge of students, an online form was applied. The online form consisted of eleven questions based on the research objectives. For the treatment of the data obtained in the observation of conversation and in the online form, descriptive analysis was used. From the previous reading of the records and responses, there were identified patterns and relationships in the data that described the key concepts on the subject. The transcription of significant examples was used to communicate the findings.

3.2 Implementation

Based on the literature review and students' prior knowledge (from the conversation and online form), the educational product was elaborated. It was structured in the form of a set of interdisciplinary teaching activities. Each teaching activity addressed the content using a methodology that favoured students' participation, stimulating the construction of knowledge in an active learning process. The activities sequence is also considered a better articulation between the different contents, providing an evaluation of its relationship, in this case, the technologies and possible changes caused by them in labour and society (Zabala, 2008). The set consists of three teaching activities:

i. History of industrial revolutions;
ii. Industry 4.0 technologies;
iii. Economic, social and employment challenges.

The content and methodology of each activity is explained in more detail in section 4. In that section is also presented the tasks that were performed by students in each activity and that make up the research dataset. The researcher's observation during the application of the educational product also was used as a data collection method for evaluating the process and the results of the proposed activities. It is characterised as systematic observation and participation, implemented synchronously with the teaching activities application. In the same way as for the planning stage data, descriptive analysis was used to explore students' production and researchers' observation during didactic activities. A previous reading of the data was performed to identify patterns and relationships. The transcription of significant examples was presented. Additionally, statistical treatment was applied to the quantitative data.

3.3 Evaluation

To identify the students' perceptions about the activities and assimilation of contents, an online form was employed. It was structured using direct questioning of students, applying a mixed questionnaire, i.e. open questions (dissertation questions) and closed questions (objective questions). Once more, the data collected in final forms were analysed by descriptive analysis, using both transcriptions to qualitative data and statistical elements to quantitative data.

4. Educational Product

The proposed educational product is interdisciplinary teaching activities performed in three units. The main public is students from a high school integrated into vocational education. The main goal is to promote reflections on Industry 4.0 technologies and their implication in society. Figure 1 shows a schematic view of the proposed educational product based on the three units.

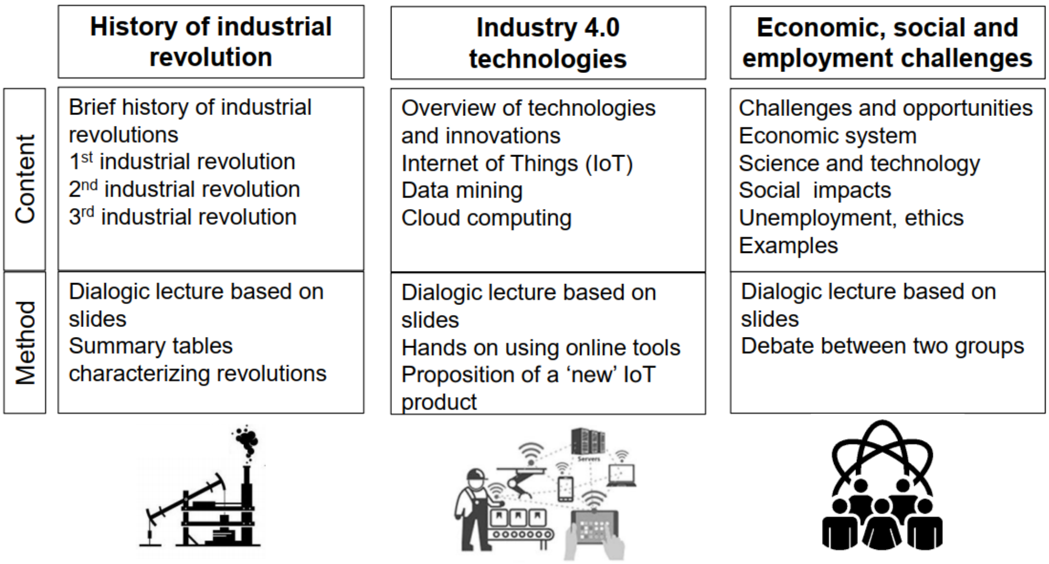

Fig. 1 - Schematic view of the proposed education product

The first unit is the presentation of the historical perspective of industrial revolutions, addressing the various changes that have affected the industry throughout history, focusing on solutions and technologies which aimed to improve its performance and the main impacts on labour and society. Contents, summarised in Table 2, are:

i. Introduction and motivation - Brief history of industrial revolutions
ii. First industrial revolution
iii. Second industrial revolution
iv. Third revolution
v. Conclusion and final consideration

Table 2 - Industrial revolutions versus technologies versus work and society impacts

Revolution	Technologies	Work and society
1st Industrial Revolution Beginning in England in the mid-18th century	Steam energy and water Mechanisation/Machines Increased production Focus on the textile industry The invention of new transport systems (locomotives and steamships)	Industrial capitalism had a big boost Rural exodus to cities From craft production to machines Various forms of work have become archaic, generating unemployment Workers Became Salaried Workers Long working hours and low wages Children and women even more exploited Creation of unions and labour strikes
2nd Industrial Revolution Beginning in the USA in the late 19th and early 20th centuries	Electricity and Oil Energy Mass production Assembly line Fordism/Taylorism Inventions: lamp, combustion engine, the telegraph, telephone, television, among others The emergence of Automotive Vehicles and Airplanes	Division of Manual and Intellectual Labour Time control in production systems Work organisation State action Machines drastically replacing humans Fordist system crisis Flexibility in production Multifunctional workforce Increased quality of life due to technological inventions
3rd Industrial revolution Led by the USA beginning in the mid-20th century	Old and new Energies: oil, hydro, nuclear, wind, with a focus on clean energy Use of information technology and automation in industrial processes	Reduction in the use of labour due to automation and robotics Globalisation Environmental awareness Increased social inequality and exclusion Improvements in working conditions

	Inventions: Industrial Robots, Telecommunications Satellites, Personal Computer, ATM, Mobile Phone, Tablet-Software, GPS System, Automotive Technologies

The methodology used in this first activity was a dialogic lecture based on slides, presenting characterisation and the impacts of the industrial revolutions on the production systems. After the explanation, students were tasked with filling in a summary table, characterising one of the industrial revolutions considering: the pioneering country, factors that drove this pioneering spirit, energy sources, main raw materials, and a synthesis of the impacts on society at the time.

In the second unit, some technologies arising from Industry 4.0 were presented. Once there are many technologies involved, three of them: artificial intelligence and data mining; internet of things; and cloud computing. These technologies were chosen once they have a great relationship with industry applications and people's daily lives. In addition, these technologies do not require a high degree of technical knowledge for understanding, as there are easily accessible solutions which can facilitate students' learning and interest. Topics discussed were:

i. Introduction and motivation concerning the Fourth industrial revolution
    - Historic context
    - Overview of technologies and innovations
ii. Internet of Things (IoT)
iii. Data mining
iv. Cloud computing
v. Online access to related tools and examples
vi. Conclusions and final considerations

The methodology applied was a dialogic lecture class using slides, followed by a hands-on practical activity in which the students were encouraged to experiment with some of these technologies through free online tools. In addition, students were asked to propose a new IoT product or equipment based on some requirements, demonstrated in a schematic figure and a description.

The third unit aimed to promote a discussion based on literature and the proposed subject. The approach is to raise reflections on the positive and/or negative interference/challenges in the economic, social, and labour, considering the transition to the fourth Industrial Revolution. The topics covered were:

i. Introduction and motivation
ii. Overview about challenges and opportunities concerning Industry 4.0 technologies
    - Economic system
    - Science and technology
    - Social
    - Unemployment, basic income
    - Examples, solutions, discussion
iii. Discussion based on groups
iv. Conclusions and final considerations

A dialogic lecture using slides was employed to give an overview of some authors' points of view, followed by a debate between students. The suggested debate separates students into two groups. One group is encouraged to list opportunities and positive views of the technologies and the other challenges, problems, and negative points. In the final, both groups promote a discussion, being moderated by the teachers. The contents for each unit, such as the teaching formats and methodologies used, were selected according to the students' prior knowledge exploited previously and their comments during the activity's application.

5. Results and Discussions

The proposed interdisciplinary activities were conducted online due to the COVID-19 pandemic. The developed activity was recorded so students could participate synchronously or asynchronously, but it was preferred synchronous participation. The findings are shown below.

5.1 Planning Stage

In relation to the diagnosis of participants' prior knowledge, the online round of conversation was employed for identify students' prior knowledge. From the guiding questions, students reported having heard the term "Industry 4.0". However, they were incapable of describing it and did not know exactly what it would be. Participants related this term to the idea of greater integration of the internet and intelligent machines. It was verified that students reported that Industry 4.0

influences society by creating some "new" professions, such as UBER driver and iFOOD couriers. Therefore, the outsourcing of services:

> *"In the beginning it would bring threats such as underemployment, but later on, society would adapt and follow the normal system" (S.O.).*

> *"A large part of people thinks it is good, but another part thinks it is bad, considering that having no income, people cannot consume, interfering with the economy" (C.A.).*

During the conversation, the students were unable to formulate opinions or ideas about previous industrial revolutions and their influences on society, they only have the historical concept of the facts. They reported the importance of understanding how technologies could influence work and the relationship with their education, justifying that:

> *"We developed technologies and therefore need to know their consequences" (C.A.).*

Concerning examples about any technologies which changed society and work, they reported:

> *"Technology is already part of the industry, in the service sector, it enables outsourcing in the UBER transport sector. Qualification is required in the presence of machines" (OS).*

In addition to the conversation strategy, an online form was applied. Nine students answered the proposed questions. It was possible to confirm that the students had already heard about the term Industry 4.0. Still, they were unable to conceptualise it, did not have a clear idea about it, nor were able to reflect on its impacts on society. Few students could cite technologies from the fourth industrial revolution, indicating IoT and artificial intelligence. Some of them indicate technologies from the previous industrial revolution (not related to the fourth one), so it seems that which technologies were applied in each revolution were unclear. Most students believe that the technologies of the fourth industrial revolution could influence work and/or society, however, they did not know-how. All participants believe that the technologies of Industry 4.0 could influence positively and negatively work and/or society.

In the request to cite an example of how technology would influence work and/or society, indicating the technology and its influence, four of them relate automation process and, therefore, the increase in unemployment, mainly in the industrial sector. Artificial intelligence was also cited by a participant as an optimisation process, also considering an increase in unemployment, therefore. Some citations were:

> *"I've seen a video of a truck, I think paving or something, without a driver, being controlled. Although interesting, this technology could take jobs away from people who drive means of transport".*

> *"Automation processes extinguish low-skilled jobs".*

> *"Automation would be even more applied but taking jobs away from employees".*

About previous revolutions, most participants expressed their belief that the technologies influenced the labor and society of their time. The number of participants who were unable to give their opinion on whether the technologies influence the labour and/or society was much lower in this case than for the fourth industrial revolution, which indicates that students were still not able to appropriate the impacts of these new technologies on current society.

From the perspective of whether this influence was positive, negative, or both, all of them responded that the influence of technologies in previous revolutions was positive and negative. When asking them to cite an example of how they influenced, indicating the technology and its influence, the main topics were manufacturing - machinery, electricity, rural exodus aiming for better wages. Some students did not indicate the influence. Some citations were:

> *"Machine manufacturing, for example, replaced manpower to machines".*

> *"In the past, there was a job to turn on and off streetlamps and maintain them, which were powered by oil. This job was extinguished with electricity, electric lamps, and with LDR that automatically turns it on and off according to the external luminosity".*

All participants considered it important to discuss Industry 4.0 and its impacts on work and society in their professional education.

5.2 Educational Product Implementation Stage

The first unit, History of industrial revolutions, aims to provide students with a historical perspective of industrial revolutions. As evaluation, students were asked to draw up a summary table of an industrial revolution of their choice. In this framework, it was necessary to fill in the chosen period, the pioneer country, factors that drove this pioneering spirit, energy sources, main raw material, and, finally, a synthesis of the impacts on the society in the chosen period. Thirty-five summary tables were developed, being: 66.0% referring to the first industrial revolution; 6.0% referring to the second industrial revolution; 17.0% referring to the third industrial revolution and, finally, 11.0% endorsing all industrial revolutions. Table 3 presents the results.

Table 3 - Results of industrial revolutions chosen by students to develop summary tables in the first moment

Revolutions chosen by students	N	(%)
First industrial revolution	23	66.0
Second industrial revolution	02	6.0
Third industrial revolution	06	17.0
All industrial revolutions	04	11.0

It was verified by analysing the summary tables that students achieved the proposed objective, which was to find out if they could raise the main information on industrial revolutions in different areas (technology and society). However, the preferred chosen analysis for the first industrial revolution is notorious. Thus, it appears that they cannot relate the cumulative process of industrial revolutions and reflect on what these impacts would be on the work and society.

In the second unit, Industry 4.0 technologies, the main objective was to introduce students to technologies from the Fourth Industrial Revolution and their applications in industry and peoples' daily lives. Among the practical activities, artificial intelligence for cognitive services tools provided by *Microsoft Azure* were used. Tools for computer vision, face detection, and verification were tested. It was verified that the activity stimulated students' curiosity by using their own photos in applications. Students' reflections during practical activities are structured in such a way as to recognise the importance of technologies to improve peoples' quality of life and their possible performance in industries. For instance, in an application for peoples' age detection based on a persons' photo, some results of the artificial intelligence application were not accurate, which implied they were asking about drawbacks related to this technology on society, such as in the use of facial identification in the resolution of crimes.

As a final activity, the participants, in pairs, were motivated to propose an IoT product or equipment, containing the following minimum requirements:

i. Schematic diagram of the equipment;
ii. Consider at least ONE sensor and ONE internet-connected device;
iii. Describe its working principle, its functionalities, and main advantages.

Sixteen product proposals were analysed, considering the fulfilment of the proposed requirements. In addition, it was verified if the proposed product could be characterised as an IoT equipment. It was verified that all equipment proposals met the requirements, indicating that students were able to understand the topic. All proposals also considered the use of some cloud computing services, such as the storage of collected data. Furthermore, 31.2% of the proposals were able to indicate in the description the use of artificial intelligence tools, using data mining techniques in the data collected by the suggested product.

A proposal for an intelligent IoT headset is highlighted. The product could identify the language of a person with whom someone would want to communicate, performing instantaneous translation by the user. It was a clear example of the need for sensors (microphone), actuators (headphone speaker), need for IoT devices capable of sending data to the internet, using cloud computing tools and artificial intelligence both to transform audio into text, language recognition, translation of text into the language of the user and finally transform the translated text into audio for the user. On the other hand, it appears that only 6.3% of the proposals included an example of industrial application. All others focused on applications in the students' daily life, such as household and hospital products. In this way, it is evident that the research participants, who are from high school integrated in industrial automation vocational courses, are still not able to reflect on the applications of technologies in industrial applications, potentially more linked to the focus of its course.

In the third unit, Impacts of the Industry 4.0 technologies, students were encouraged to reflect on the future, suggesting possible impacts of Industry 4.0 on society and work. During the dialogic lecture, the perception of students is observed when they consider science and technology as products which are not neutral, but of social relations under the capitalist economic system, in a contradiction relationship between the technological possibilities of satisfying the basic needs of human beings and of counterpoint, consequences such as hunger and unemployment. They also reported the adaptability of workers to the various changes that the labour market imposes and the growing use of technology in the areas of services, such as people transportation which uses UBER App, and fast food considering iFood App. Then, based on information presented on the first and second units and their experiences and reflections on the topics discussed, a debate was proposed in which students should compare different positions and points of view.

The proposal aims to reflect on what would happen (possible impacts) in the fields of industrial production, employment, medicine, transport with the large-scale use of algorithms. Would it result in mass unemployment? Would new occupations appear? What are the opportunities and challenges facing this situation? The debate was organised into two groups, separated into online rooms. One group listed the opportunities and positive views of the technologies. The other listed the challenges, problems, and negative points. Students could not choose the group that would develop the argument, so they should reflect on the arguments of the group defined by the teacher. Each group was moderated by a teacher and represented by a rapporteur. After this round, both groups returned to a common online room for discussion, being moderated by the teachers.

The group which defends the challenges of the use of technologies in the labour market brings to the discussion the question about the understanding of science and technology as products of social relations under the capitalist economic system. Some citations were:

> *"The use of technology and science is not neutral, there are positive and negative impacts, more concentrated on profit". (M.C.)*
>
> *"It requires more human precision, efficiency and as a consequence, there is a massive deficiency". (M.C.)*

As algorithms and machines increasingly remove humans from the labour market, not replacing them in the same proportion, it causes unemployment, loss of rights, and social inequality. They suggest as an alternative to overcome this issue, the application of "Basic Income". The argument was that a basic income would maintain the country's consumption power and economic stability. They also reported the importance of international organisations interfering in access to science and technology, such as the distribution of the vaccine against COVID-19 by the World Health Organization from developed countries to poor and underdeveloped countries

Participants also cited the participation of society in union council and ethical conduct adjustments. Its participation would mitigate the possible negative consequences of applying technology in the labour market, as a way to guarantee the permanence of labour rights and avoid their precariousness.

The group that defended the opportunities and positive view of the use of technologies asked about:

> *"No denial of the benefits of the use of technologies for people's lives, through its use in the fields of communication and interaction as it is today." (S.O.).*
>
> *"In the educational environment, it made it possible to advance teaching remotely, in the health sphere, the development of more accurate diagnoses, in the work sector, will not take jobs away, but it is a natural transition process that can be regulated by unions and adjusted by political groups." (LB)*

It is concluded that the students were able to reflect on technological advances and their consequences in different fields such as employment, health, education, and transport. They recognised science, technology, and education as primordial principles for humanity and not for capital accumulation by a restricted portion of the population.

In industry, what drives is a reconfiguration of the production model, which starts from the results of human actions, configured according to their personal project and collective project, the worker must be seen as a collaborator and not exploited. Critically, education is seen as a demand of the production process. It is possible to highlight the citation:

> *"The installation of our school, to establish itself in the industrial centre of our city, with the objective of training workers." (S.O.)*

In the final considerations of the debate, it was clear the intention of not exhausting the discussion, providing new debates, studies, inquiries, and discussions on the subject.

5.3 Educational Product Evaluation Stage

Forty students from the fourth year of high school integrated in industrial automation were invited to participate in the proposed work. Due to the COVID-19 pandemic, the proposed units were conducted online and were recorded. Students could participate synchronously and asynchronously. The participation rate in synchronous classes is shown in table 4.

Table 4 - The number of students participating synchronously in the three proposed units

Proposed unit	N	(%)
All units	14	35.0
Two units	08	20.0
Only one unit	04	10.0
None	14	35.0

The evaluation results are presented in table 5.

Table 5 - Results for the interdisciplinary teaching activities evaluation

Question	(%)
The didactic sequence piques my interest	
I fully agree	41.2
I agree	52.9
Neither agree nor disagree	5.9
I disagree	0.0
I fully disagree	0.0
The methodologies employed were pleasant and favoured your learning	
I fully agree	58.8
I agree	35.2
The methodologies employed were pleasant and favoured your learning	
Neither agree nor disagree	0.0
I disagree	5.9
I fully disagree	0.0
The language employed was clear?	
I fully agree	52.9
I agree	47.1
Neither agree nor disagree	0.0
I disagree	0.0
I fully disagree	0.0
It is important to discuss the impacts of Industry 4.0 technologies on work and society in your vocational course?	
I fully agree	82.4
I agree	17.6
Neither agree nor disagree	0.0
I disagree	0.0
I fully disagree	0.0
The organisation of the didactic sequence attracted your attention	
I fully agree	47.1
I agree	47.1
Neither agree nor disagree	5.9
I disagree	0.0
I fully disagree	0.0
Units/classes time duration in relation to the covered content was adequate.	
First moment - History of industrial revolutions	
Short	0.0
Adequate	70.6
Long	29.4
Second moment - Industry 4.0 technologies	
Short	17.6
Adequate	76.5
Long	6.9
Third moment - Economic, social and employment challenges	
Short	11.8
Adequate	76.4
Long	11.8
The reflections raised are consistent with your reality	
Yes	82.3
No	6.9
Kind of	11.8

It was verified that 94.1% of the students fully agreed or agree that the proposed activities piqued their interest and the methodologies employed were pleasant and favoured their learning process. All of them indicate that the language used was clear, which is very important concerning students' age, who may not have relevant experience in the industry environment. All participants also agree that it is very important to discuss the impacts of Industry 4.0 technologies on work and society in the course. Regarding the structure and organisation of the proposed activities based on three units

(History of industrial revolutions, technologies of Industry 4.0 and finally, its impact on the society), 94.2% agreed that they attracted their attention. It seems that the duration of the first unit could be shortened once 29.4% indicated that it was long. The other activities seem to be adequate.

Finally, 82.3% of the participants indicated that the reflections raised during the activities were consistent with their reality, demonstrating that it was essential to use the hands-on strategy not based on algorithms for industrial applications but in their daily activities. In addition, it was verified that most of the products were not suitable for industry, but in their routines. Thus, it was important to show technologies and some authors' points of view to motivate their own reflections, which could be reinforced in the following years when they might be working in a real industry. By analysing students' answers concerning their opinion on how the new technologies of Industry 4.0 could influence work and society, it was clearly verified that in their perception, new technologies influence work and society, having 52.9% indicating both positive and negative influences. The concepts that most appear as the negative influences were reduction in the number of jobs at a greater rate than the creation of new occupations, causing unemployment; increased economic inequality; the constant demand for adaptation and training of the employee, facing new requirements. As positive influences, students have cited that adopting new technologies such as computation, robotics, automation, IoT, and intelligent systems would increase productivity, quality of services, and efficiency in industries. According to them, it would be positive to replace manual, repetitive, dangerous, and exhaustive labour, which could increase employees' free time for their leisure and healthcare. From this scenario, some believe that the emergence of new occupations and the extinction of others is a natural process.

Seventeen students answered, indicating a real example of how technology could help in activities performed by people today, explaining whether the technology would partially or totally replace the work to be performed. They indicated the technology, the occupation, and explained how and at which level the technology would transform the activity. It was possible to verify that 35,3% presented the healthy sector as an example, followed by the transport sector with 29.4% of the citation. Other areas were industry, education, dangerous occupations, and drive-thru services. Concerning the health sector, replacing humans with robots in surgeries, medical exams, and diagnoses was present, relating to less human error in procedures and more incredible speed and accuracy in diagnosis. The replacement would take place partially due to the importance of human awareness regarding patient empathy. In the transport sector, intelligent and interconnected systems are used, such as autonomous cars and UBER, avoiding human failures, accidents, and less environmental impact due to less circulation of cars. They believe that human replacement could be total. Some ethical issues also appear, such as liability and possible accidents in autonomous cars. The other sectors refer to the industry, being considered better performance and decision-making based on the IoT database. In education, the possibility of using technology to replace teachers. Considering dangerous occupations was cited as replacing man with a machine in situations involving danger. Finally, the drive-thru calls were mentioned, where it would be easily replaced by robotics and supervised by man.

The last approach is related to the belief that society in general (government, private initiative, non-governmental organisations, and other institutions) could take actions to mitigate the possible negative impacts/challenges of Industry 4.0 technologies in production processes. What actions could be proposed? Participants were asked to explain this action by indicating responsible agents and how they could mitigate the impacts. It obtained seventeen responses, 47.1% of them cited the government as responsible for conducting the actions, followed by 23.1% referring to unions, 11.8% held the companies responsible for this role and 11.8% considered the responsibility of society in general. Those who believe that the government is responsible emphasise the importance of guaranteeing a basic income and social assistance to workers, imposing an ethical limit on the use of technologies, demanding employer limitations to maintain labour rights, and encouraging political and social debate aiming to develop a social and personal awareness of the society. The answers confirm the importance of guaranteeing high-quality education, encouraging innovation, guiding the use of technology in different sectors, training workers, and using technologies in the labour market.

Those who suggested unions as agents indicate their responsibility by guaranteeing workers' rights, continuous training, and appreciation of workers' categories. When indicating companies as agents, it highlighted the need for training its employees, encouraging the exchange of experiences, and minimising the negative impacts by relocating their employees to new jobs. Society appears as an agent to provide high-quality education accessible to workers to relocate to new functions/occupations or reinvent their workforce. To sum up, it was possible to verify that students raised many hypotheses regarding the benefits and challenges of the impacts of Industry 4.0 technologies on work and society, and there was a consensus that the solution is not the denial of these new technologies.

6. Conclusion

This work aimed to investigate, develop and analyse the student's conception of the impacts of Industry 4.0 technologies on society, through a proposal of teaching activities considering an interdisciplinary approach. The education product was expected to contribute to the students' formation, increasing their motivation and learning, promoting them to reflect on the relationships that have been established between technologies and their impacts on society and labour. The educational product was proposed and developed from action research methodology, being elaborated, applied, and evaluated with students from technical education integrated to high school in industrial automation course at the Sertãozinho campus of the Federal Institute of Science, Education and technology of São Paulo. Thus, the results presented are limited to the data collected from these participants. It was verified that the developed product provided to the participating students, conditions to reflect and analyse industrial revolutions and some technologies of the called Industry 4.0, within a historical context, considering the origin and evolution of production systems and scientific transformations. This enabled students to reflect on technological advances and their consequences from a critical perspective, identifying strengths and challenges in different fields such as employment, health, education, and transportation. Thus, they could integrate social, scientific, technological, economic, and political concepts witnessed in their daily lives.

Providing the same educational actions to high school/ professional students, this work contributes to overcoming the duality that crosses the entire history of Brazilian education between professional versus intellectual, scientific teaching and manual versus intellectual work. A critical point in the development of this project was the need to apply the educational product during the COVID-19 pandemic which required to be adapted to a non-presential strategy. However, given the positive numbers, it was considered that the activities were successful in their application. The range of discussions and concepts addressed by students during the development of the project shows that the proposed educational product could be applied in other contexts, both in professional and in basic education from the polytechnic formation perspective.

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