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Analysis of Learning Developed by Industrial Engineering Students in a Simulated Work Environment

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Abstract: In 2015, the School of Chemical Sciences carried out a connection agreement between the academy and the industrial sector. This was done to strengthen the specialized training of the Industrial Engineering with a minor in Management's students, resulting in the creation of the Simulated Work Environment (SWE) to benefit the educational practice of both, the Universidad Autónoma de Nuevo León and the industry. The training in the SWE is oriented to the learning of the diverse techniques of World Class Manufacturing in a production line. In this study, the students' degree of knowledge and experience, regarding World Class Manufacturing, is analyzed. This analysis happens before and after experiencing the training to compare their prior knowledge before and the acquired learning after doing the practice. Additionally, different physical, environmental and social factors that have an impact on the students' learning are analyzed with the aim of improving their learning experience. As for the methodology, the reasons for the research were defined first, then, after that, the background of the subject was studied. Subsequently, two questionnaires were developed as measurement tools, one for input and another for output, to inquire about the students' prior and final knowledge. The input questionnaire was applied to a sample of 149 students. The output questionnaire was only applied to 41 students due to the COVID-19 pandemic, which prevented the continuation of the programmed training for the rest of the students and therefore the questionnaires were not applied. The analysis of the partial results showed that the students managed to improve their acquisition of theoretical and practical knowledge of World Class Manufacturing in an effective way. This happened through experimental, meaningful and collaborative learning in the SWE, enhancing their experience as Industrial Engineers.

Keywords: Simulated Work Environment, Students, World Class Manufacturing

1. Introduction

The university academy is always in process of continuous improvement (Esquivel Valverde et al., 2017), looking for diverse ways in which students get significant knowledge, so they can use it in the labor market when they graduate. The application of this knowledge is carried out in laboratories, where experiments, practices and work are carried out, with the aim of representing or approaching the reality of the labor market (Franky, 2009).

It has been shown that the brain tends to ignore the learning when this is not used or linked, integrating them during and after the training process (Yáñez, 2015). For students to put into practice the theoretical concept studied in the classroom, the productive sector and the academy establish connection agreements and work together to create work environment simulators that provide students similar experience or recreation of a real work environment. It is important to mention that the use of a simulator promotes the active learning, where students play the leading role of the teaching-learning process (López Guede et al., 2018). Knowledge becomes significant, since the students themselves gather information, select, organize, and set up relationships with previously gotten knowledge; that is, they relate the added information with the one they already have (Cálciz, 2011).

Additionally, the student develops discovery and experimental learning. Since in discovery learning, the student discovers, relates, and rearranges the concepts to adapt them to their cognitive scheme (Cálciz, 2011). It is important to mention that in experimental learning, the student in the experience of the real environment, performs a process of self-reflection to learn (Gutiérrez Fernández et al., 2011).

During the practice session, students work collaboratively, taking distinct roles and proposing solution alternatives and improvement opportunities (Felder & Brent, 2009; Felder & Brent, 2001). Therefore, students' learning processes are not generated alone, but take part in a social activity interacting with other students (Shum & Ferguson, 2012). Thanks to the active and collaborative activities, carried out in the real simulator, the teaching-learning process becomes more active, dynamic, interesting, involved and significant (Zuluaga-Ramírez & Aguirre-Henao, 2014).

The Simulated Work Environment (SWE) aims to strengthen continuous industrial training and specialized practical training for students in the ninth semester of the bachelor degree in Industrial Engineering with a minor in Management career. Students carry out laboratory practices to learn actively and meaningfully. In a simulated work environment close to the real one, the topics analyzed in class during the last semesters are applied. The production of goods in a simulator is carried out under automotive industry real conditions, putting into practice various strategies and tools of World Class Manufacturing (Feld, 2000).

The main objective of this work is to analyze the learning degree of Industrial Engineering students regarding to World Class and Lean Manufacturing topics when carrying out the SWE training. In this research, the degree of knowledge acquired and the experience of students regarding World Class Manufacturing strategies and tools were evaluated. The knowledge before and after experiencing the training in the simulated work environment was compared through surveys applied to the students. Additionally, factors that could have an influence in learning such as physical, environmental and social factors were analyzed in order to improve the learning experience of students.

2. Methodology

For this study, two measurement tools were designed with the aim to analyze the grade of knowledge of the students and the factors that influence learning before and after carrying out the training in the simulated work environment. The input survey measured the current level of knowledge before the practice and the output survey measured the improvement in knowledge and some factors that influenced the grade of learning during the training.

The input survey was divided in two sections, the first one related to demographic data such as age, sex, academic degree, etc. in addition to level of knowledge for each word class manufacturing topic. The survey enquires about the knowledge and application expertise of the world class manufacturing topics through self-assessed questionnaire using Likert scale. Table 1 shows a list of the main topics that are developed in the SWE training and that are measured in the input survey.

Table 1. List of topics that are strengthened in the SWE training

1. 5 S's	2. Standard Work	3. Visual Control
4. Eight Wastes	5. Lead Time	6. Takt Time
7. Added Value	8. Line Balance	9. Pull System
10. One-Piece Flow	11. Kanban	12. Poka Yoke
13. Andon	14. Stop & Go (Stop and Fix)	15. TPM
16. Just in Time	17. Kaizen	18. Value Stream Map
19. Process Validation	20. Safety First	

The output survey was divided in two sections as well as the input survey, the first part explains the purpose of the survey and enquires about personal data and work position during SWE training. The second section enquires about the knowledge and acquired learning during the SWE training through self-assessed questionnaire.

The second part of the output survey shares more similarities with the Likert scale, since it is intended not only to evaluate the knowledge acquired from the students, but also the internal and external factors from SWE training itself that could have an influence in learning. These factors were divided into 5 blocks plus the block to assess knowledge: 1. Laboratory elements, 2. Environment, 3. Physical condition (before starting the laboratory practice), 4. Physical condition (during SWE training), 5. Team Leader and Section Manager ability, 6. Learning efficiency.

The topics were the same as those used in the input survey, which were put into practice during the SWE training. Finally, the answers were processed and analyzed, comparisons were made, and final report was obtained.

3. Analysis and Results

The input survey was applied before the students attended the simulation and the output survey was applied after attending the SWE. The input survey was answered by 149 students and the output survey was applied only to 41 students due to the COVID-19 contingency that prevented the continuation of the scheduled simulations and therefore the application of the rest of the surveys.

As a general aspect the results show that before attending the SWE most of the students express that they master the subject “5´S” followed by the concepts “Takt time” and “Poka Yoke”. On the contrary, the least understood subject was “Stop & Go” followed by the topics “Andon” and “Process validation”. The output survey showed that the best understood topic was “5¨S” and on the contrary the least learned topics were “Stop & Go” and “TPM”. According to the coincidence, it follows that “5´S” is a relatively easy topic for the student to assimilate and put into practice, so it is easily understood in the simulation. On the other hand, the topics “Stop & Go” and “TPM” are more complex practical topics, so the results suggest that they should be rethought more clearly in the training, in order to improve the degree of learning.

The results obtained from both, input and output surveys allow the analysis of the degree of learning and the factors influencing simulation within the SWE. The degree of learning for this study is defined as the difference between the level of learning in the output survey minus the level of knowledge before doing the training in the SWE. The overall average of the degree of learning for the total sample resulted in 1.3. For the analysis, this overall average was contrasted with the degree of learning acquired by sections of the sample, according to each of the external or internal factors that were analyzed. The results were as follows:

Work *situation of the students*: The students who did this training and do not have a job or do an internship (professional practices) represent 10% of the population. They presented a learning grade of 1, which is less than the average learning grade of 1.3 of the total sample of all students.

Operational position of the students: In the SWE practice the students are divided into 4 teams, distributed in 4 sections of the production line, and these in turn are composed of 4 positions, where each member shares position with a colleague; except for the position of Materialist (water spider). The Figure 1 shows the detail of SWE training positions.

Operation position 007D and 008D (Team 3) had the most participants, 17%. The Materialist (Team 4) had the least number of participants, 2%.

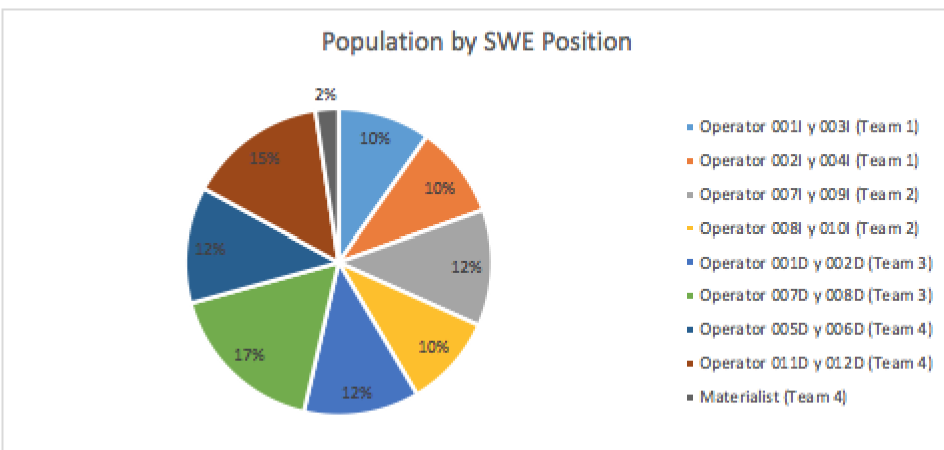

Figure 1. Population by SWE position

The Figure 2 shows the relation between the SWE position and learning degree results. Operator position 001D and 002D (Team 3) shows a higher average learning grade than the rest, which resulted as 1.5. The Materialist position (Team 4) shows the lowest average learning grade of -0.1.

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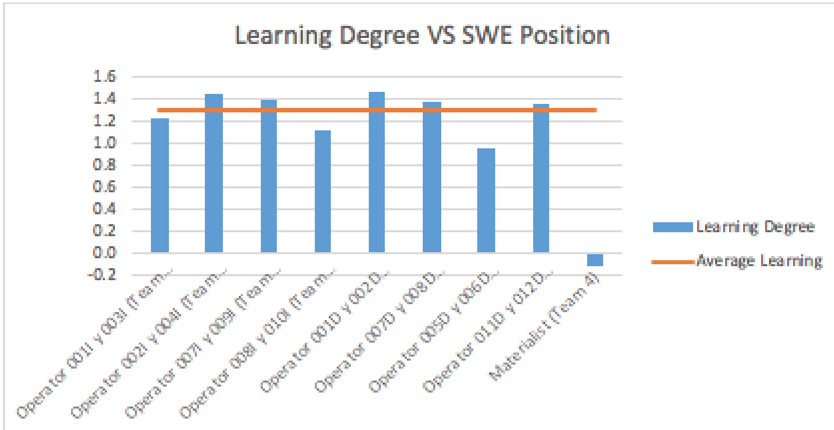

Figure 2. Learning Degree vs. SWE Position

Clearly explained practice objectives: 10% of the students mentioned that the objectives to be achieved in the SWE were not clearly explained to them. Resulting in a learning grade of 0.6, which is significantly below the average learning grade.

Sufficient laboratory materials: Only 7% of the students mentioned that the materials were not sufficient to carry out the SWE practice in a best way. This aspect did not affect on the average learning grade since this grade on students was equal to the average of the general learning of 1.3.

SWE temperature: 21.9% of the students showed a non-conformity with the temperature of the work area when performing the training. These students showed a grade point average of 1.17, which is below the overall learning average of 1.3. While remaining 78.1% only falls 0.02 points short of the overall learning average.

Motivation of students before and during SWE: Students who were not motivated before practice but who changed their attitude during the practice and increased their motivation level, showed a learning grade average of 1.6, higher than the general learning average. Students in the opposite situation showed a lower performance of 0.9.

Student´s feelings of tiredness, sleep, and hunger before and during SWE: The students who had some of these sensations (tiredness, sleep and/or hunger), before starting the practice and who stopped presenting this unfavorable sensation, showed a better performance in their degree of learning compared to the students who continued presenting some of the mentioned conditions, or who presented them during the practice. Those who did not show fatigue, sleep and/or hunger before starting the training and finished it without these sensations showed less learning than those who were able to counteract the sensations at the beginning of the practice.

Muscular illness or injury of the students: Only two students presented a state of illness at the time of the practice. These students had a lower than average level of learning.

Motivation: Another aspect evaluated was the motivation of the Team Lead and the Section Manager towards the students. Students who considered that Team Lead and SM motivated them during practice reached an average learning grade of 1.3. However, those who were not motivated turned out to be below average, so it can be deduced that this external factor directly influences the degree of learning obtained in practice.

Team Lead and Section Manager knowledge: Another aspect of the assessment is the knowledge, preparation and ability to lead the practice by the Team Lead and Section Manager. Some students who expressed that their Team Lead and Section Manager mastered the practice achieved the average in terms of the degree of learning. However, those students who expressed that their Team Lead and Section Manager lacked knowledge were below average, so it follows that this factor directly influences the degree of learning achieved in practice.

Team Lead and SM´s ability to explain and give feedback: On this factor students who considered that they were explained and given adequate feedback during the training achieved a degree of learning equal to the average. However, those who were not adequately explained were below average, so it follows that this factor directly influences the degree of learning obtained in the training.

Comparison between input and output: A scale of 1 to 5 was used to evaluate knowledge about World Class and Lean Manufacturing in both surveys. The minimum level of knowledge that students should have about Lean and World Class Manufacturing concepts was defined as 3.5, considering 70% of the maximum level of knowledge. Figure 3 shows a significant improvement when comparing the input and output results. In the output survey only 24% of the sample demonstrated the minimum required knowledge of Lean Manufacturing. On the other hand, when analyzing the output data, it was observed that the knowledge index rises to a percentage of 97.5% of the sample. It follows that the SWE training had a positive and quantitative impact on the knowledge of the students in the Industrial Engineering Manager who performed the practice.

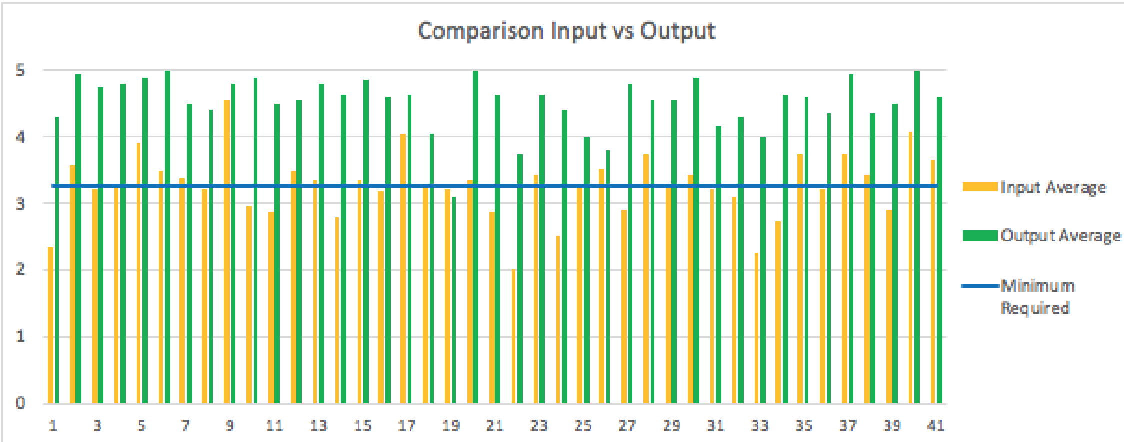

Figure 3. Comparison of input results vs output results

Learning degree: The Figure 4 shows the variation among all the students who attended the SWE training, as it can be seen in some cases this learning degree is very low, however, it does not mean that in all the cases the final knowledge of the student is insufficient, on the contrary, even in some cases the final knowledge reaches almost the level of knowledge 5, later on the cases will be explained specifically.

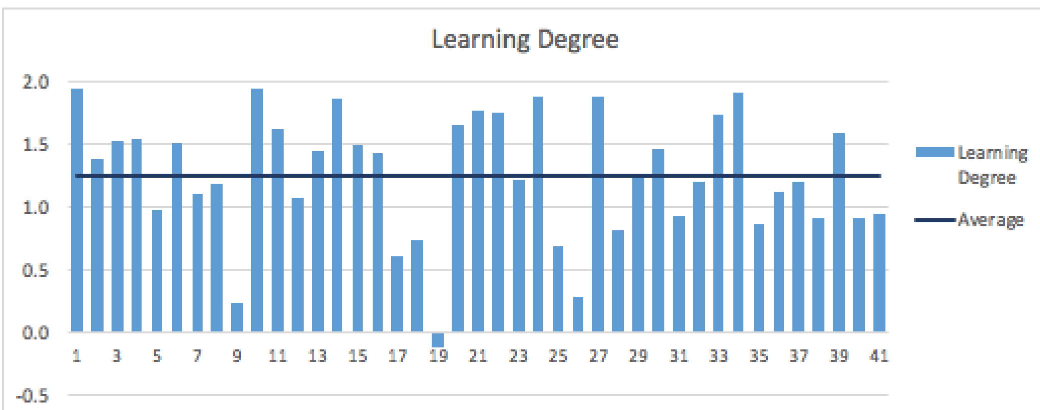

Figure 4. Learning degree

Top 3 Best results: Following the earlier results, three students were analyzed in greater depth and showed a higher degree of learning than the average for the entire sample analyzed. It was found that none of these students belonged to the same work team within the SWE, so it is concluded that this is not a factor that influenced their learning. According to the demographic data, the three students were studying the 9th semester and doing an internship (professional practices). None of them coincided in a specific work area or in the line of business. One of them woks in logistic department, another in real estate development and another in maintenance department.

Another interesting aspect is the average knowledge in the input survey of each student, obtained before the SWE practice. All three students were below the minimum requirement of 3.5. Once these three students attended the SWE training and having answered the output survey it was observed that the average learning acquired by these students exceeded the

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minimum required knowledge by a considerable amount (3.5), having results very close to knowledge level 5 as shown in the Table 2.

Table 2. Top 3 Best results

Concept	1	2	3
Input Average	2.34	2.95	2.73
Output Average	4.3	4.9	4.65

Therefore, it is deduced that significant learning could be encouraged if the conditions of these students would be replicated. These three students show a great coincidence in their learning outcomes as well as in their evaluation of internal and external factors, laboratory material and even the capacity of their leaders in the SWE, with the exception of the adequate temperature for student number two, who considered it to be inadequate; however, this difference did not directly impact the result in the degree of learning.

Top 3 Minor results: On the other hand, the three students with the lowest degree of learning were analyzed. By reviewing in depth the factors that influenced the three lowest results, it was found that two of these students belonged to the same work team within the SWE training, so we can conclude that this was a common factor that influenced their learning, in addition to the fact that one of them had the role with the highest workload as a Materialist (Team 4). As for the demographic data, all three students were in their 9th semester and they were doing an internship (professional practices), however, none of them coincided in a specific department. On the other hand, the average of one of these students before the SWE with the respect to general knowledge of Lean and World Class Manufacturing was below the minimum required of 3.5. Once these three students attended the SWE training, the average of the acquired learning increased, in one of the cases having results very close to the level of knowledge 5, however the specific student already had a considerably high level of knowledge so it can be deduced that he was limited to learn more, since he already had good knowledge of the subjects.

4. Conclusion

Based on the results, it can be concluded that the training in the SWE definitely has a positive and quantitative impact on the increase in knowledge and skills of the students of the Industrial Engineering program. Additionally, it was found that the set of unfavorable internal and external conditions can limit the learning capacity of the student in the SWE, while the favorable conditions promote the practical, meaningful and collaborative learning that is sought to be achieved.

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