

EDUCATIONAL SIMULATION TECHNOLOGY FOR WELDING
MÉTODO DE FORMACIÓN EN SOLDADURA POR SIMULACIÓN CON REALIDAD AUMENTADA

SOLDAMATIC



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COMPARATIVE STUDY ABOUT WELDING TRAINING: **TRADITIONAL METHOD VS. SOLDAMATIC AUGMENTED TRAINING METHOD**



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INTRODUCTION

This study is intended to compare in a real course the welding training model that has been applied until nowadays, versus the new methodology proposal of SOLDAMATIC AUGMENTED TRAINING focused in optimizing costs, time and resources available by a pioneer use of Augmented Reality, aimed to augment the trainees motivation and therefore their qualification.

The welding instructors themselves recognize that the traditional training method is suitable but inefficient: high costs and little effective time for practice which provides, in many cases, low qualified professionals unable to attend the industry requirements, besides the possibility of physical risks for the students and harmful gases emissions to the environment.

Apart from the particularities of each welding process, the courses follow a common pattern which means that all the trainees start the course simultaneously receiving the theoretical contents in a conventional classroom, and after the hours established in the training program all of them pass to the workshop to practice with real welding equipment taking for granted their previous knowledge, as not all of them learn in the same way. In the workshop, there is usually just one instructor for all of them, and this together with the fact that the practices are done individually (one booth for each trainee), makes it impossible for the instructor to monitor what every student is doing, so the mistakes are going to be later detected and corrected. In short, this methodology is only structured in basis of the contents of the course instead of the trainees' capacities and their learning progression; and this is due to the fact that the traditional means do not allow an individual training as it is very expensive. Fortunately, the technological evolution provides us with new tools that reduce the costs and even simplify the instructor's labor.

It is also important to highlight that the materials and the welding consumables are expensive so they should be used the best possible, but this does not occur: the trainees learn most of the time in their own way, so the materials are not fully used. This mainly depends on factors like previous skills, the interest shown, the capacity of concentration, etc.

Finally, all the trainees finish the course simultaneously and normally obtain their Certificate, which is the same for all of them regardless of their acquired knowledge and experience.

This model is not only about welding training but it happens the same in any technical discipline, since it is believed that the only way to assimilate these kinds of subjects is to practice until acquiring the necessary knowledge and skills that must be carried out in a job.

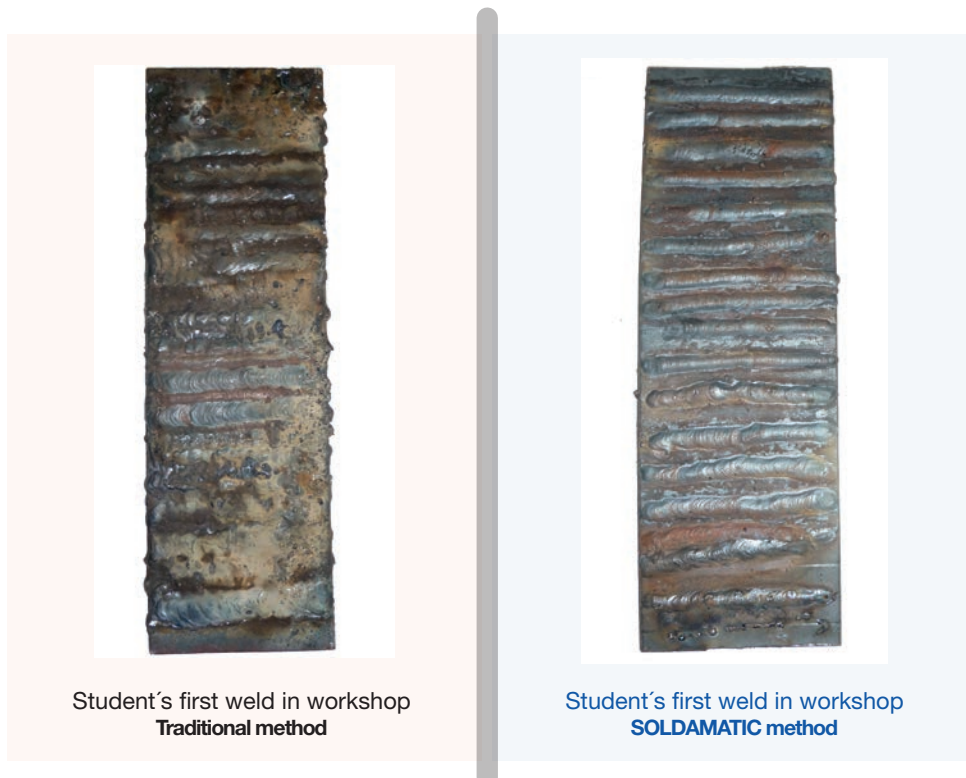
The problem comes when those practices are expensive or even imply a physical risk and contamination, as it happens in welding training. For this reason, it would be desirable to limit those practices but without reducing the quality of training; otherwise the main objective would be lost.

Moreover, in the current economic and global crisis where all the budgets, including the ones addressed to education, are being notably reduced, the problem is even worse, since all those cuts have a direct impact on the practice time, which finally means a cut in the quality of the training. In the initial levels of training, the trainees do not have enough previous knowledge, so they need more time of practicing and a greater use of the resources, and this current situation do not help to achieve that aim.

Technology must contribute to overcome all these problems, and the training model SOLDAMATIC is proposed to solve this situation. It is not intended to modify the contents of the courses, but simply organize them in a different way to obtain a better assimilation and provide a greater number of effective practicing, offering an incredibly realistic environment where the student follows the same steps and experiences the same sensations as if he were at his workplace, so the trainee will pass to the workshop once he really dominates all the skills and knowledge.

SOLDAMATIC is an educational technology for welding training which uses an interactive simulation together with Augmented Reality and offers a wide range of features and possible configurations to the different weld processes, and in turn, to the different training courses since the initial to the most advanced levels.

The SOLDAMATIC methodology consists on improving the traditional method with the help of technology to make it more efficient, augmenting the training quality with more effective practicing hours while reducing the costs, and at the same time avoiding physical risks and gas emissions. Besides, it encourages the incorporation of women into the traditionally male industrial sectors. Basically, with SOLDAMATIC you can train a greater number of welders in a shorter time, better qualified and with a considerable cost saving.



SWA INTRODUCTORY COURSE. TRADITIONAL MODEL VS. SOLDAMATIC MODEL.

This experience consisted on a comparative study between the traditional training method and the training proposal of SOLDAMATIC. The first one is composed of two stages: firstly, all the theoretical content is given in a conventional classroom, and secondly, the trainees pass to the workshop to do the practical exercises. The SOLDAMATIC one, starts providing the theoretical content through the e-SOLDAMATIC learning platform and then the trainees pass to the training center with a combination of theory and simulated practice in the SOLDAMATIC classroom, to finally finish their practices in the workshop with real equipment.

We have developed an Introductory SMAW Course by using both the traditional method and the SOLDAMATIC one simultaneously. This meant a pioneer worldwide training experience, since although the SOLDAMATIC simulator is being commercialized with success in different countries of several continents, it is the first time that such an innovative training proposal is displayed as a whole and is directly contrasted with the traditional model to analyze its advantages.

To carry out this initiative, SEABERY, promoter of the training model SOLDAMATIC and the simulation technology with Augmented Reality, reached a collaboration agreement with Huelva City Council (Spain) who provided the facilities to develop the training and also cooperated in managing the experience in an active way.

For this purpose, we had several conventional classrooms and a welding workshop fitted with suitable machinery and components, smoke extraction system, and cabins for up to six welders simultaneously. It has been added all the technical and security material needed, and the necessary consumables for the development of the course always accomplishing with the current security and health regulations.

The number of submitted applications to the course was very high, covering the available capacity more than sufficiently. For this reason, both the Huelva City Council and SEABERY through its welding instructor who run the training experience, did together a selection of the students in basis of the following criteria during the months of January and February of 2013:

- Young people under 22.
- Without gender distinction.
- Unemployed.
- Without previous welding knowledge.
- Minimum level of education: Secondary Education Graduate

Finally 6 students were selected to carry out the course following the traditional method, and two students were selected to participate in the SOLDAMATIC training model, both of them with identical contents and with the same objectives.

The reason of selecting 2 students for the SOLDAMATIC model was that there were 2 student-simulators available for this study and this means that the 2 students would be under equal conditions to make the training without sharing the simulator. However and in anticipation of a shorter total duration of the course under the new model, 4 more students were selected as substitutes to the SOLDAMATIC model, so once the 2 students passed to the real workshop, another 2 substitutes would start the training in the simulation classroom.

The course consisted of the following contents:

Theoretical content:

- Unit 1: Theory of welding.
- Unit 2: Selection of welding sticks.
- Unit 3: Operative technique.
- Unit 4: Labor risk prevention.

Practical content:

- Electrical arc striking.
- Travel speed.
- Electrical arc length.
- Angles.
- Intensity.
- Junctions.
- Weld rods with electrode stick movement.
- Recharges.
- Welding sequence.
- Fillet T-angled horizontal welds.
- Fillet T-angled flat welds.

The presentation of the training experience to the students took place on 8 March 2013 and it officially started on 11 March. Before this, the students of the SOLDAMATIC model could accede to the theoretical contents in the e-learning platform, so they could assimilate the theory at their own pace and from their homes, without pre-establish timetables and without the necessity of assisting to the training center. An online test prior to the beginning of the course, determined which of them had acquired the necessary knowledge to pass to the simulation classroom, thus ensuring that only the ones that showed interest and were really prepared continued with the training.

Once in the training center, the students that followed the traditional method started in the classroom with an instructor receiving the same theoretical contents, while the students of the SOLDAMATIC method began in the simulation classroom practicing from the very first day at the same time that they reviewed in the simulator the previous acquitted knowledge.

When the hours of the traditional method were fulfilled, the students passed to the workshop to practice with real welding equipment. The trainees of the SOLDAMATIC method, however, passed to the workshop as the instructor, together with the system of monitoring, analysis and assessment of the software-professor, considered that they had reached the appropriate level.

It is important to highlight that both methods had their own welding instructor with a similar great deal of experience and qualification.

COURSE PARAMETERS:	Traditional method	SOLDAMATIC Method	Savings
Available posts	6	2	
Total course length (hours)	80	40	
Total course length reduction	0%	50%	
Hours for theory	24	0	
Hours for SOLDAMATIC	0	20	
Hours for real workshop	56	20	
Workshop time reduction	0%	64%	
Total trained students within the expected time	6	8	
Student / available post ratio	1:1	4:1	
Trained students within the same period ratio	100%	400%	
EXPERIENCE WITHIN THE WORKSHOP:			
Practice time regarding total workshop time (except plates and borders preparation, brush, etc.)	60%	60%	
Effective welding time regarding practice time (time in which the student makes correct weldings during the practice time)	30%	95%	
Real effective time regarding total workshop time (time in which the student makes correct weldings during the total workshop time)	18%	57%	
CONCEPTS:			
SCHOOL SUPPLIES: Welding manual, papers, pens, etc.			
Per student	25,00€	0,00€	100%
Per course	150,00€	0,00€	100%
WELDING INSTRUCTOR:			
Cost /hour per student (Euros)	3,50€	3,50€	
Total cost/student (Euros)	280,00€	140,00€	
Total cost/course (same number of students)	1.680,00€	840,00€	50%
Total cost/course (total trained students)	1.680,00€	1.120,00€	33%
CONSUMABLES:			
SMAW			
SOLDAMATIC time per student (hours)		20	
Consumed welding sticks SOLDAMATIC classroom		0	
Average consumption of welding sticks per student/hour	12	12	
Workshop hours per student	56	20	
Average consumption of welding sticks per student /course	972	240	
Average cost/welding stick (Euros)	0,1677€	0,1677€	
Total cost of consumed welding sticks/student/course (Euros)	112,69€	40,25€	
Total cost of consumed welding sticks/course (same n° of students)	676,17€	241,49€	64%
Total cost of consumed welding sticks/course (total trained students)	676,17€	321,98€	52%
Plates (6 mm thickness)			
Consumed plates SOLDAMATIC classroom		0	
Average consumption of plates per student/course (meters)	5	2	
Cost of plate meter (Euros)	5,00€	5,00€	
Total cost of consumed plates per student/course (Euros)	25,00€	10,00€	
Total consumption of plate meters /course (same n° of students)	30	12	
Total consumption of plate meters/course (total trained students)	30	16	
Total cost of consumed plates/course (same n° of students)	150,00€	60,00€	60%
Total cost of consumed plates/course (total trained students)	150,00€	80,00€	47%

	Traditional method	SOLDAMATIC Method	Savings
INDIVIDUAL PROTECTION EQUIPMENT:			
Work clothes, masks, gloves, glasses, etc.	40,00€	40,00€	
Average cost per student	240,00€	240,00€	
Total course cost (same n° of students)	240,00€	320,00€	
Total course cost (n° of trained students)			
* Regarding the Individual Protection Equipment (IPE), there is no difference in the costs for each of the students, since, although in the SOLDAMATIC method the trainees spent less time in the workshop, they must wear their IPE at all times. The saving of the SOLDAMATIC method would be calculated without taking into account the courses but periods of time that involve more than a course, as the IPEs do not suffer many damages in only one course.			
WORKSHOP SUPPLIES:			
Sawing blades, radial cutting and roughing discs, inactive screens, maintenance and wear of the welding equipment, etc.			
Maintenance cost of SOLDAMATIC (€uros)		0,00€	
Average cost of workshop supplies per student/hour (€uros)	1,00€	1,00€	
Workshop supplies cost per student /course (€uros)	56,00€	20,00€	
Total cost of workshop supplies (same n° of students)	336,00€	120,00€	64%
Total cost of workshop supplies/course(total trained students)	336,00€	160,00€	52%
POWER CONSUMPTION			
Average cost w/h (€uros)	0,0002€	0,0002€	
SOLDAMATIC practices			
Consumption w/h		500	
Average consumption per student (w/h)		10.000	
Average cost per student /course (€uros)		2,00€	
Total course cost (same n° of students)		12,00€	
Total course cost (total trained students)		16,00€	
Workshop practices			
Consumption w/h (real welding equipment)	2.400	2.400	
Average consumption per student(w/h)	80.640	28.800	
Average cost per student (€uros)	16,13€	5,76€	
Total course cost (same n° of students)	96,77€	34,56€	
Total course cost (total trained students)	96,77€	46,08€	
Total cost of SOLDAMATIC practices + workshop (same n° of students)	96,77€	46,56€	52%
Total cost of SOLDAMATIC practices + workshop (total trained students)	96,77€	62,56€	35%

	Traditional method	SOLDAMATIC Method	Savings
CO2 EMISSIONS:			
CO2 emissions per welding stick (mg/m3)	5,00	5,00	
SOLDAMATIC practices			
CO2 emissions per welding stick (mg/m3)		0,00	
CO2 emissions per student (mg/m3)		0,00	
CO2 emissions per student/course (mg/m3)		0,00	
Total CO2 emissions per course (mg/m3)		0,00	
Workshop practices			
Average consumption of welding sticks per student/hour	12	12	
CO2 emissions per student/hour (mg/m3)	60	60	
CO2 emissions per student/course (mg/m3)	3.360	1.200	
Total CO2 emissions per course (same nº of students)	20.160	7.200	64%
Total CO2 emissions per course (total trained students)	20.160	9.600	52%

STUDENT SURVEYS SOLDAMATIC METHOD

GRAPHIC DESIGN:

	VALUATION:											STATISTICS:										
	0	1	2	3	4	5	6	7	8	9	10	TOTAL	1	2	3	4	5	6	7	8	9	10
I think that the SOLDAMATIC presentation is attractive								1	3		4	8	0,0	0,0	0,0	0,0	0,0	0,0	12,5	37,5	0,0	50,0
The SOLDAMATIC appearance is similar to the real equipment								4	1		3	8	0,0	0,0	0,0	0,0	0,0	0,0	50,0	12,5	0,0	37,5
The SOLDAMATIC graphics are similar to the real welding							1	1	3	1	2	8	0,0	0,0	0,0	0,0	0,0	12,5	12,5	37,5	12,5	25,0
I have found useful to practice with SOLDAMATIC before passing to the real workshop								1	3		4	8	0,0	0,0	0,0	0,0	0,0	0,0	0,0	12,5	37,5	50,0

HELP ICONS ON THE SCREEN:

SOLDAMATIC symbology is easy to interpret							1	2		2		3	8	0,0	0,0	0,0	0,0	0,0	12,5	25,0	25,0	0,0	37,5
The icons helped me to understand and adopt the correct welding positions								1	4		3	8	0,0	0,0	0,0	0,0	0,0	0,0	0,0	12,5	50,0	37,5	
I think that the help icons are useful to learn welding skills							1	2		1	4	8	0,0	0,0	0,0	0,0	0,0	12,5	25,0	0,0	12,5	50,0	
All the contents practiced with SOLDAMATIC provide the basis for using them in the real workshop									3	1	4	8	0,0	0,0	0,0	0,0	0,0	0,0	0,0	37,5	12,5	50,0	
SOLDAMATIC fulfills the expectations as a didactic welding training resource							2		1	3	2	8	0,0	0,0	0,0	0,0	0,0	25,0	0,0	12,5	37,5	25,0	

CONTENT OF THE TRAINING PROGRAM

The content of the program is suitable for the current and future professional necessities						1	1	1	1	2	2	8	0,0	0,0	0,0	0,0	12,5	12,5	12,5	12,5	25,0	25,0
The content of the program is suitable for the course duration					1		1	1	1	4		8	0,0	0,0	0,0	12,5	0,0	12,5	12,5	12,5	50,0	0,0

TRAINING METHODOLOGY:

SOLDAMATIC exercises and practices are very useful to understand and apply the concepts in the real workshop								4		3	1	8	0,0	0,0	0,0	0,0	0,0	0,0	50,0	0,0	37,5	12,5
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E-LEARNING RESOURCES:

Content facilitated by the e-Soldamatic platform						1			3	3	1	8	0,0	0,0	0,0	0,0	12,5	0,0	0,0	37,5	37,5	12,5
Exercises, submitted documentation and support material						1	1	1	2	1	2	8	0,0	0,0	0,0	0,0	12,5	12,5	12,5	25,0	12,5	25,0

INSTRUCTORS' BEHAVIOUR:

Instructor's response to any theoretical or practical query										1	7	8	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	12,5	87,5
Availability when he is required										2	6	8	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	25,0	75,0
Involvement in the course development										2	6	8	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	25,0	75,0

TOTAL:

	0	0	0	0	0	3	8	17	22	31	54	136	0,0	0,0	0,0	0,74	2,21	5,88	12,5	16,18	22,79	39,71
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I AM GENERALLY SATISFIED WITH THE COURSE DEVELOPMENT:	0	8	8
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CONCLUSIONS

The first general conclusion that can be drawn is that the training experience has been very positive and this is based on the students' opinions who have declared that they all feel very satisfied with the course.

In general, the advantages associated with any simulation training system are the cost and time savings, but in the specific case of welding, it must be added savings in energetic consumption and in gas emissions that affect the environment as well as the elimination of physical risks during the activity. The intention was to quantify all those savings in order to compare the efficiency of both training models.

Nevertheless, all that have been said would not have sense without appreciating the quality of the training itself, since one of the main goals of SOLDAMATIC is not to reduce the quality but even to increase it, to achieve better students' qualifications through motivating them and having more effective hours of training (real hours of welding).

The results obtained have been very clarifying and favorable to the SOLDAMATIC method in all compared parameters.



Student's last weld in workshop
Traditional method



Student's last weld in workshop
SOLDAMATIC method

As explained before, this study had 6 students following the traditional method and 2 following the SOLDAMATIC one. Despite of this, 8 students have been finally trained with the SOLDAMATIC method, that is the 2 students initially selected plus the 4 forecasted substitutes. Besides, all of them finished the course even before the expected date, so 2 women were incorporated to it. In short, the ratio of the students trained in the same time has been 1:1 for the traditional method versus 4:1 for the SOLDAMATIC one, therefore obtaining a 400% increase in trained students. In other words, even despite of having a 66% less available training stations Soldamatic was able to train more students than conventional training in the same time.

It is also important to emphasize the last-minute women incorporation because one of the main objectives of SOLDAMATIC is to promote the incorporation of women into industrial sectors, through a reduction on the impact that involves the use of the industrial equipment and machinery in an uncomfortable and dangerous environment. This was verified with the excellent results obtained by the 2 women, even without receiving the previous orientation that their classmates did.



Regarding the above, a 50 % reduction in the total time of the course has been verified, that is, while the students of the traditional method have completed the expected 80 hours for this module, the trainees of SOLDAMATIC have made the same training, with the same level of quality in only 40 hours.

Moreover, there has been a higher and proportional reduction in the workshop time, where more resources and consumables are used. In fact the SOLDAMATIC method only consumed a 36% of the required time. In other words, it has been verified a 64% reduction in the necessary workshop time without affecting the quality of the training. All this has produced very important savings that are going to be described below.

Regarding school materials, the traditional ones like pens, papers, etc., are not necessary with SOLDAMATIC, since all the theoretical content is available in the Teacher-software and it is taught through the e-SOLDAMATIC platform and the student-simulator. For this reason, the saving concerning this aspect is 100%.

The cost of the instructor has been reduced by 50% for the same number of trained students and this is due to the total duration of the course that is shorter now, and not to a cut in the teacher wages. However, in the SOLDAMATIC method there has been a 33% reduction, since the number of trained students is higher.

With respect to the consumables and checking the average consumption of electrode sticks and carbon-steel plates, there is a saving of 64% and 60% respectively with the SOLDAMATIC method and with the same number of students. If the total number of trained students at the same time is calculated, there are savings of 52% and 47%.

Regarding the Individual Protection Equipment, there is no difference in the costs for each student since although in the SOLDAMATIC method the trainees spent less time in the workshop, they must wear their protection equipment at all times. The saving of the SOLDAMATIC method should be calculated for larger periods of time that involve more than a course, as the protection equipment do not suffer many damages in only one course.

There is saving of 64% to the same number of students in materials like sawing blades, radial cutting and roughing discs, inactivic screens, maintenance and wear of the welding equipment, etc.; and a saving of 52% if we take into account the greater number of trained students at the same time with SOLDAMATIC.

Due to the fact that the students spend less time practicing in the workshop, the consumption of electrical power has a saving of 52% regarding the same number of trainees. Taking into account the 8 trained students with SOLDAMATIC versus the 6 trainees that are carrying out the traditional method, the saving is 35%.

Finally, one of the main objectives of SOLDAMATIC is the sustainability that contributes to avoid the gas emissions of the global warning, and regarding this it has been verified that there is a saving of 64% in CO2 emissions with the same number of students, and of 52% if we calculate all the students that are really trained.

As a consequence of the above, the results are clearly favorable to the implantation of SOLDAMATIC in the economic, energetic, environmental and safety aspects without forgetting that the students have obtained an equal or even higher qualification level than in the traditional method. For all these reasons, it can be concluded that the training model proposed by SOLDAMATIC implies a clear advantage over the traditional one, contributing to the improvement of the efficiency and the quality of the training itself, that is basic a pillar of the productivity and competitiveness of the countries, and, therefore, of their present and future.

Start using SOLDAMATIC. Start changing your mind. Start living the future.

PICTURES



PICTURES

