iQSim

Innovative Simulator Tools for Quality Management
Production Process Training in VET

Development of Innovation
Multilateral Pilot Project
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D3.2 - 3 Pedagogical Methodologies Report

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1. Executive Summary

The quality of welding is interdependence with skills of the welders. In this context skill means practical ability to create sound weld but in the same time it means also to understand the dependence of welding quality from the basic welding parameters, like parent material, joint geometry (e.g. edge preparation), voltage, current, welding speed etc.

With one word the welder should know not only the effect of his/her movements on weld quality but also the effect of the metallurgical and technology factors as well.

Today many VET (Vocational Educational and Training) schools and other training institutions are keen to develop mainly the physical skills of the welder students and student also don’t like very much theory, sitting in front of book and read etc. They are more for practice. On the other hand the theoretical knowledge is necessary – to get this teachers are using several learning tools.

iQSim was a Leonardo da Vinci Development of Innovation pilot project (iQsim 2010). It aimed to provide real-time, online and embedded mathematical calculations of complex industrial production processes that are:

- Flexible: Easy to use Flash-based interfaces that can be used to simulate «What happens if ....» scenarios which are hard to do in a lab.
- Integral: Work seamlessly with digital whiteboards by using a Flash and Flex-based point-and-click interface and sliders to adjust the parameters.
- Adaptable: Can be adapted to any number of teaching methodologies, including Activity Based Training methods.

The iQSim simulator services provide modern tools into education of welders. The iQSim simulator services are an efficient learning tool, which have the capacity to deepen the theoretical knowledge of student being welders in connection to the practice. The student can raise questions and problems gathered on workshop floor, for example what will happen if the joint geometry will be changed, what kind of effect has this fact e.g. on quantity of filler material. The iQSim simulator services, this modern learning tool, will show in a short time the answer and the changes which means the “new” quantity of filler material and economy etc. It is a good tool for learning and practising problem solution using iQSim simulator services. The simulation and modelling part is based on simplified mathematical formulas and algorithms related to fusion welding by using operational characteristics, which correspond to good practice (Nippon Steel).

We need to be aware of the fact even a welder serves a welding robot he should know the basics of creating welded joint and the effect of the basic welding parameters.
In teaching using the iQSim simulator services it is needed to have mainly electronic devices.

The simulator is designed for easy use on digital blackboards and PC-s as well by use of AIR based control interface technology. The pedagogical framework uses problem-based training with use of cases from industry to address innovations in industrial training. The services offer students and instructor’s access to a new training environment that utilizes evaluation processes where they may “play” dynamically with essential production parameters by using a “what happens if” scenario. In this way students visually understand the tolerance window occurring in real life production facilities. The simulator may from an instructional point of view, help reducing manufacturing defects by making up alternative decision routes that may handle both technical and economical production tasks.

The welder’s productivity depends on the skills of the welder. If the welder has a deeper knowledge and skills, his/her productivity will be higher, because the quality of the work is higher. In this way the repair costs is reduced. Furthermore, the welder’s decision capability will be better, and he/she will have a special transparency over the production process. Unfortunately, this it is tricky to obtain this approach in the current educational practises.

Teachers and students may use the online iQSim services to create “What happens if ....” training scenarios where they dynamically “play” with the variables of complex industrial production processes. Examples of such scenarios may be:

- What influence will the root gap have on the economy?
- Does tolerance in the bevel angle influence production costs?
- Which production methods give the widest set of production tolerances?
- Which of the production parameters have the greatest influence on the Heat Affected Zone?
- Which parameter is the most important when heat input must be maintained?

Thus, students and instructors may use learning activities where they employ sliders to “play” dynamically with essential industrial production parameters in order to observe the tolerance window occurring in real-life production facilities. It’s possible to investigate the influence and variation of a number of variables in order to figure out which variables have the highest impact on the final products. From an instructional point of view, the methods and services help optimizing the production by developing alternative decision routes that include both technical and economical production tasks. The pedagogical framework may utilize Activity Based Training solutions (Stav 2008). The knowledge construction follows a logic sequence that always starts from the simple to the complex (Alonso 2004). The teaching scenarios and consequences for new training methods combine the perceptive and cognitive aspects in a simulation perspective (Bodic 2004, Arias-Jordan 2005).

The results include educational material and simulator services addressing
• Defining material constants
• Selecting geometries
• Fine-tuning the geometry
• Select welding methods
• Display temperature in Heat Affected Zone

The iQSim services perform cost and economical calculations. The evaluation tools include the most frequently used welding methods: MMA, TIG, FCAW and MIG/MAG, as well as tools for evaluation of the most frequently used joint configurations or bevels:

• Square butt (I-bevel)
• V-bevel
• Fillet weld
• X-bevel

Calculation of production costs for the four welding methods and bevel configurations above, are included.
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7. DISCUSSION AND CONCLUSION

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2. Background

Welding tasks within mechanical industry production is one of the critical skills and key constraints to economic growth and development in Europe. A range of new international standards developed support immediate needs for skills development in industrial applications and practices. Training offered in combination with job and industrial production activities, is one of the best available training methods since it is planned, organized, and conducted at the employee's worksite. Such training will generally be the primary method used for broadening employee skills and increasing productivity.

The needs of the national markets vary with regards to training. Welder training is often focuses on specific jobs and processes that must be executed according to standards. Professionals must acquire certificates, which must be renewed frequently to ensure that critical processes are executed according to safety standards. Training may vary at the national level based on the national certification scheme, the national market demand for specific competence in industrial production tasks, and other factors. International benchmarking and comparative quality assurance standards for international qualifications, certification and licensing have lead to a European Community Standard for education and training for welding stakeholders in 30 countries and education of 50,000 new welders each year. The joint international guidelines define the required profile of education, knowledge, experience and responsibility for a range of mechanical industry production tasks and provision of professional assessment procedures.

Excellent teachers provide more than just lecturing. They organize the curriculum into an educational system, by establishing a suitable learning environment where tasks and assessments are integrated in order to encourage certain study paths. Learning results are indeed obtained through stimulating, enjoyable and engaging good lectures. The teacher should even in large classes, from a practical point of view, manage to adept their teaching methods based up on students responses. This includes both misconceptions as well as conceptions within the subject domain. One way of using technology from learning centered approaches to achieve responses from a class is by using open, web-based simulator services.

Unfortunately, online welding simulator tools that are available on the market in Europe to help Vocational Education and Training (VET) schools, instructors and welders to make up user friendly production process training, are targeting the welding process only and movement of the torch. The idea behind the iQSim new services and new training methods, are that the teachers and students need to evaluate a set of physical parameters in order to find out which parameters are the most important to fix in an industrial production process solution. The simulator services are designed as a dynamic tool to be used in an evaluation process. It is not
going to be a tool for carrying out calculating of a specific result. Instead the service should be used to answer questions like:

- What happen if I select another value for a parameter?

Thus, the simulator services are going to provide a tool for evaluation of consequences within industrial production processes training. From a pedagogical point of view we want the students to make modifications, and evaluate the consequences of the proposed results that these modifications yields. We are not interested in the exact answer, but rather in the differences or relations that the modifications will give.

**Blended learning methods**

While working in industry, it is expected that learners participate in skill development programs. Thus, training delivery methods must take into account limitations in terms of time and location. It should further be noticed that in a professional environment learners could benefit from each other’s knowledge and skills, as much as through the interaction with an instructor.

Distance learning services provide us with an opportunity to offer and deliver education and training to geographically distributed end-users by making it more attractive and cost-efficient. Video supported training try to create an educational environment offering geographically separated end-user groups a taste of presence by introducing virtual mobility for teachers and/or students. That is, the communication technology offers learning experiences where teachers and students work and collaborate together without being physically at the same geographical location. Advanced distance education and training solutions offered to groups of students may utilize a blend of learning technologies. Pedagogical methodologies often utilize a blended learning and training solution that constitutes of the following training elements:

- Traditional classroom structured instruction with face-to-face training where the trainer(s) and the students meet
- Self-paced learning by using Learning Management Systems (LMS)
- Hands-on practical training and collaborative laboratory work
- Inclusion of various video services offering high quality multipoint real time communication to groups of students by using video streaming and videoconferencing

Videoconferencing offers a communication and collaboration environment where audio and video are transmitted in real time between two or several locations, across, in principle, unlimited distances. Many videoconferencing systems communicate data in parallel (e.g. a Power Point presentation), whereby they are suited for distance training purposes. Instructional processes utilizing videoconferencing take advantage of the communication technology developments
by offering real time face-to-face communication in distance teaching settings. It should be noticed; however, that videoconferencing as a standalone tool has rather limited effect in distance educational settings, since it only offers components of the training elements needed within skills upgrading processes and education. There is, however, numerous of successful frameworks, which combine videoconferencing with various e-learning solutions.

At the operational level, the blended learning pedagogical approach mixes the following components in a skills upgrading process:

- Instruction and/or guidance by using high quality videoconferencing in combination with digital blackboards and document cameras. This solution uses advantage of video communications technology developments for real time face-to-face communication in distance teaching settings.
- Hands-on practical training, possibly at the contractor site, where groups of staff may work together regularly during a production process.
- Self paced collaborative online learning by utilizing short, targeted industrial streaming video clips.

Such training methods reduce training related costs, both in terms of travel expenses and in terms of time off work. The latter includes the disruption to the work schedule pre and after training related travel, as well as the disruption to the lives of professionals as it usually takes a few days to get into the normal work rhythm. The increased face-time and the limited use of self-paced learning in the context of a wider skill development strategy is a step forward from traditional distance teaching and learning. Distance learning solutions are often not applicable in industrial training processes due to reduced quality as compared to in-class instruction. Furthermore, utilization of video conferencing promotes training to take place intra- and inter-company, often across borders, in the context of a global industrial production economy.

iQSim develops and disseminates a new generation of blended training methodologies that are applicable to European mechanical industry sectors (fabrication industries, large organizations as well as SME’s, and VET schools). iQSim services are prepared for use together with blended learning frameworks, as the services have been designed for use on digital blackboards. In the framework of iQSim the manual for SMARTBOARD was prepared and circulated to the members of the consortium. Thus, they may easily be transferred by use of videoconferencing to, as the digital blackboard is transferred as a second, parallel videostream. The availability of videostream on the web is possible because the address is circulated as well. Innovative online simulator services that include embedded state-of-the art Computer Algebra Services provide easy to use graphical interfaces that optimize cost- and time effective transfer of industrial production process and technology know-how to VET students. The combination of new pedagogical methodologies and simulator services, extend the existing training methods by offering an
evaluation process of the production process when it starts, during a training session, and when it has been completed.

**Outlining the iQSim simulator services**

Instructors and welders have been used the simulator tools to simulate the proposed data for a selected set of welding parameters. For each selected welding process it is typically 8-12 parameters like current, voltage, thickness, material type, joint configuration etc. that must be selected. It is within a certain span a dependency between these parameters, whereby they may not be selected independently. It is critical to adjust these parameters in the best possible way to obtain the best technical quality, and the most cost efficient production solution.

The simulator tools offer instructors and welders extension of existing training paths and access to new training environments where they may state and select the most favourable combination of parameters for the selected welding process, thus avoiding accelerating costs as well as welding defects by offering the right quality before and after an industrial training session.

It is expected that the iQSim simulator services are going to disseminate a new generation of simulation services that will generate new training methodologies that are applicable to European wide mechanical industry sectors. The on-line simulator services provide easy to use graphical interfaces that optimize cost- and time effective transfer of industrial production process and technology know-how to VET students. The combination of new pedagogical methodologies and simulator services, extend existing training methods.
3. How is training provided in the welding sector

The European Pedagogical Challenge

The start up of a welding career depends on the age of the welder. In many countries the basic skills can be given through the school system at 9th and 10th class. However outside the school system a number of training facilities may offer their services. This may be adult training institutions, either as public institutions or as commercial players in the market.

Smaller companies have often limited access to training resources and the use of training institutions may solve this problem. However, SME’s (Small and Medium Enterprises) also often only require a limited amount of skills and processes and this may limit the scope of the training to one process, but this can provide a good foundation for skill development on a life long skills upgrade process.

Larger companies may have their own training school, which covers a number of processes and materials. Such training facilities will normally be focused on the company’s need and practices thus focusing for a kind of on-the-job training, which may be seen as a disadvantage from a general education point of view. However, such education, although containing a general and harmonized content may also include a lot of company specific know how that allows each participant to gain an extensive amount of additional knowledge that normally is a part of a life-long learning cycle.

Adults who want to change their careers usually need to acquire the basic skills of welding before applying for employment as a welder. Information about these courses is available from local Job Centre. Full-time courses are run by different institutes varying in length from two to ten weeks, depending on the coverage required or if the course shall lead to a Diploma or a Certificate or both. The fees vary according to the process and the extent of the training.

Welders aiming at obtaining one or more welders certificates have to carry out regular updates of these certificates in order to maintain their validity. Such updates may also require additional training.

Although this scenario means that the training services are fragmented and may differ from country to country, the above observation seems to be general in nature. The fragmentation also leads, it seems, to little experimentation of the pedagogical methodologies. Very few initiatives have been carried out on a European scale to alter the traditional pedagogical methods.

Common for the welding education and training has been and still are an education based on a blend of traditional classroom education mixed with practical skills training in a laboratory or workshop. The theoretical education has been and still is given through lecturer with course books and with help of overhead, power point presentation and also to some extent, use of targeted CD or DVD sessions with video of ex 10 to 20 minutes. Such CD or DVD sessions will normally cover one general
topic like Welding with MIG-MAG process, Plasma cutting and so forth. That means for a student point of view that the process is shown and explained as an overview or as a combination of an overview with detailed topics covered into the same session with detailed explanations.

However for the practical training some new virtual technologies have emerged the last 4 years on a limited scale. Through the international fair: Schweissen und Schneiden in Essen, Germany in 2009, virtual welding was for the first time shown on a larger scale. This technology is now slowly penetrating into the training market in order to lower the material, equipment and other welding related costs. But the pedagogical method seems so far not to be influenced by introduction of these virtual methods.

As a summary, it looks like the pedagogical approaches on a European basis haven’t changed much during the last 20-30 years.

**National Pedagogical Approaches**
Through a closer look at the national approaches to education and training we will find that they are the same among the countries in the project consortium. The differences will more be cosmetic due to the differences in the industry sectors in the project countries. The industry sectors vary from offshore industry with one-off production in Norway, to boiler and heavy industry, with variant and serial production in Hungary, to shipbuilding industry and general supplier industry in Lithuania.

These different industries requisites different welding methods and different materials, giving the impression for people not knowing the welding industry, that there are significant differences in the education and training, while the reality is that the differences that can be seen are depending on the welding processes only. However the pedagogical methods used in the different training scenarios in the project countries, are the same.
The situation in Norway
The welding education in Norway is organized in basically two different ways.

1. Through the public school system where the (young) students may select to specialize in welding. The education and training in welding is part of the normal education plan for the school.

2. Through institutes and other organizations as vocational education and training courses. Such courses are organized at certain intervals, or when they get a sufficient number of students to arrange course.

Elementary welding courses
Elementary welding courses, offered through an institute or private organization, may have a time span from one to four weeks. The length depends of the scope of the course, as well if the students shall obtain a welders certificate. Due to the industrial production company’s dependency of the offshore industry, the focus has usually been education and training that leads to a valid welders certificate. Most of the certificates are verified by approved 3-party like Det Norske Veritas (DNV), Teknologisk Institut (TI) or similar. Unlike the situation in many other European countries, 3-party verification of the certificates is the main rule (or habit) in the industry. Welding Diplomas are not yet common although this seems also to be coming in the future for the Norwegian education and training market. The International Welder (IW) scheme seems to be the one that will be accepted by the industry.

Recertification courses
One major education and training activity is the recertification courses of certified welders. A welders certificate is valid for two years. It can, in Norway, be automatically prolonged for another two years under the condition that

- the welder can prove that he/she has been welding with the process for which he/she has been certified
- with the materials, thickness and welding positions that the certificate covers

A valid test of the joints that have been welded is accepted as a proof of the work. Such proof must be given every 6 month.

Furthermore, a welder in Norway has in average 4 to 5 different certificates whereby the probability that one or more certificates lacks the right proof for recertification is relatively high. The consequence is that the welder passes a new welding test every 2 year. Recertification courses covering a couple of days training is therefore common.

The students
Based on the above we can categorize the welders into three categories:
1. First time welder being educated and training through the school system. The age of these students are up to 20.

2. Adult welders getting their education and training through institutes or private education centres

3. Adult personnel going through a recertification scheme.

Figure 3.1: Graph showing the age distribution of welders in Norway.

The age distribution of welders in Fig. 3.1 displays at least three interesting aspects, which should be discussed in more details.

a) It is obvious that a number of welders are not educated through the ordinary school system. This means that a high number of welders are educated through courses after the ordinary school education have been completed. This means that such courses may be part of on-the-job training, or part of additional education carried out. It may also mean that people with different background takes special courses in order to start a new career as a welder. It should be noticed that the theoretical background for the welders is obtained through the welding course itself, whereby the long term effect is that they may have limited theoretical knowledge for the job they are going to carry out. They will gain their practical skills during the lifelong learning process.
b) It is also evident that a number of welders stop welding when they become older. This means that they either get new job positions, which do not require them to renew their certificates in the companies where they are working, or they change into another type of job. For instance, some of these welders will be promoted and get other types of positions like foremen etc. There aren’t any research results available that may document the knowledge transfer between the various generations of welders.

c) Investigations have shown that a relative higher share of students that selects welding education, have been people that have problem with learning theoretical subjects in the usual school system. It is expected that this fact is connected to reading and writing problems, as well as a general problem with the motivation for learning theoretical material at a young age.

The graphical distribution in Fig.1 may indicate that such students leave school as soon as the opportunity is available, and then return at a later stage for further practical oriented education provided by the institutes. On the other hand, it may also indicate that the education and pedagogical strategy should be more practical oriented, and use visual communication solutions for transfer of knowledge and competence in the educational content. Today an overwhelming part of the content is written material, and web-based search for content.

Intermediate findings through questioning teachers who provide training of welding personnel at this level, indicate that an higher number of students than usual, have problems with their reading skills. Similar effects are also observed with colour recognition when welding classes are compared with other classes in the school system. This indicates that the use of visual communication solutions and methodologies will strengthen the educational environment, if it is combined with a face-to-face communication.

An additional study made in Norway in 2004 documents that there are an over-representation of foreign people in the age of 25 to 35 in the population of welding personnel. This indicates two new aspects.

• It may be difficult for foreign workers, especially from outside Scandinavia and Northern Europe, in getting theoretical office jobs, whereby they consequently are looking for work in sectors that require practical skills and where it is a lack of skilled people.

• These people are educated through short courses aimed at adult education. They are not getting their competence, which is valuable, the labour market, through the public education system. This may lead to a lack of general theoretical background knowledge for the education, because no special education has been obtained on the technical side from the school system they have gone through in their native countries. They will receive some theoretical knowledge through the welding course, but it will be very limited. However
the mechanical skills in moving the torch or electrode will be adequate with such education.

**The teachers and instructors**

Most of the teachers engaged in welding education are actually old welders. Basically they have one or more certificates. They have obtained their experience from welding in industry for some years, and then start working in the school system. Some of these teachers have additional pedagogical education, as well as higher technical education at a medium level. Usually the teachers and instructors have to teach the technical aspects, training of practical welding skills itself, as well as the theoretical education.

**The pedagogical approach**

The pedagogical approach is to a large extent (up to 90 %) traditional classroom based education. By this we mean:

- The first part of the day is based up on classroom training with course books, examination and education by use of blackboard complemented with use of CD/DVD material supplied from different welding suppliers
- The second part of the day will be in the workshop, training to perform welding tasks and gradually build up the welding skills through numerous repetitions.

Only approximately 10% of the education is provided in cooperation with local industries. In such cases the schools cooperate in building an object or product, in cooperation with industries. Such an engagement is usually based up on local initiatives and local teachers.
The situation in Hungary

Different laws control the education in Hungary. The basic laws are for: public, vocational, higher and adult education in harmonization to EU regulations. The education is organized in schools-; or in training course systems. The vocational educations, which do not belong to the higher education, are available in the so-called “Nationwide Vocational Education List” (according to the Hungarian abbreviations: OKJ) for vocational (professional) education and training. Welder is skilled worker can be employed if he/she is 18 years old and his/her health condition is good for welding job. This later is controlled and documented by inspection body for health and safety.

Welding education. System in Hungary – general information:

Welding education in Hungary is organized basically in the module-based systems:

a/ VET schools for students older than 14 years, after finishing the welder course could be qualified welder and later can have certification as well,

b/ adult training:

b1/ Hungarian system:
- vocational training for being qualified welder,
- part-vocational training e.g. for being welder specified only for one or more welding processes,
- operator training for welding-; and cutting machines,
- duration period of education: 2 years or 2000 contact hours, with obligatory practical and theoretical exams,

b2/ European system (according to the EWF/IIW rules) for education of:
- welder,
- technologist, engineer, etc.,

b3/ Hungarian/European certification and re-certification training courses if participant has gained previously welder qualification, can get after training course and exam certification valid for 2 years but it could be extended if controlled circumstances fulfilled.

c/ higher education (colleges, and universities), mainly delivering theoretical lectures and having some in workshop manual training occasions, e.g. welding in own welding workshop/laboratory and visiting factories producing welded metal structures.

All these educations could be done, if the purchasers requires, in the framework of Activity Based Training (ABT) as well.
Learning materials:
- the students taking part in any of the educational systems have professional literature, standards (ISO, EN and MSZ -Hungarian), course books, own handwritten notes, test-sheets and the programs for practical, in workshop, manual training, etc.,
- electronic learning materials are requested and developed mainly by state support also for distant learning,
- the curriculum is prescribed for vocational and adult welder students even for European training courses and programs for practical, in workshop, manual training, etc.
- the curriculum for theoretical and in workshop welding manual training in higher education is accredited by state owned “Hungarian Accreditation Body for Higher Education”,

Exams:
- The test questionnaires used for exams are unknown for participants.
- The evaluation system of test sheet fulfilled during the exam is predetermined,
- The examining board is independent from the training body.
- The time for test and oral exams are predetermined.

IQSim based simulator services in the welder educational system:

The iQSim simulator services based educating, qualifying program supports the members in vocational and refreshing welding courses to understand and follow the principles of welding technology because they understand better the interrelation between the basic technical and economical welding parameters.

After completed iQSim simulator services based training module they more easily fill the requirements of EWF and/or IIW for welder’s qualification and/or for certification and/or for re-certification.

The students

Some pedagogical related features were mentioned in the previous para. Here will be some more special pedagogic related information on behaviour of students.

Welder students are human beings mostly having problems with understanding printed material – they do’nt like to read too much. It means the teacher has the responsibility and task to make understandable the welding related professional information not only in form of books, leaflets, notes and but by explanation and by constant repetition for refreshing the professional knowledge.

Some of the students have no interest to seat and learn. They are more restless and mobile also to have a good result in pedagogical sence the teaching program should be dynamic and ready for frequent and active repetition.
The iQSim simulator services fulfill this requirements because the students have the possibility instead of passive presence to be more active and even they can play and compete to each other while learning by experience.

This effect could be deepened if they create pWPs and then they weld the testpiece according to their pWPS and later they test it and evaluate the results of their work.

The in-put requirements for students if using iQSim simulator first, is the understanding of the basic phenomena of welding and secondly having some skills for IT.

The teachers and instructors

The teachers mainly having higher education engineering diplomas and few of them can have post-graduated pedagogical qualification (like: diploma) as well.

The instructors mainly qualified/certified welders having a couple of ten years industrial welding practices. These persons generally are not young and sometimes having not enough good pedagogical education or skill because the main point was to choose them their professional skill.

iQSim- simulator services are tools for teachers to make the students sit down to table while changing the welding parameters and their effect on the results for welding could be observed. In this case the students will be inside the information chain and learn while “playing” and discussing, debating.

This special internet related capability of iQSim simulator services make simulator service an excellent tool for distance learning as well, which will spread in the future in Hungary as well.

The iQSim simulatur services are not toys but ready and able visualizing the basic features of welding process. This is a big help for learning and understanding the welding phenomena and an excellent tool for teachers e.g. explaining different features of welding, e.g. HAZ etc.

MHtE has the decision to implement iQSim simulator system as pilot program in welder’s training and IIW/EWF rules based courses.

The personnel in education team using iQSim simulator services should take part in course on simulator services organized by MHtE.

MHtE will provide for this “train the trainer” course learning material using the results of iQSim simulator project.

The pedagogical approach

Places of teaching:

Generally the iQSim simulator services used in classroom, which is furnished comfortable for ITC, based learning activity, and there are also facilities good for, in workshop, manual training.
In the class-room therefore needed to secure the good quality training conditions if using iQSim simulator services e.g.: there should be available internet connection, digital white board, PC-s, and a DVD disk having database for the whole iQSim – simulator services, and equipments for workshop-floor practices like: welding, cutting and material testing facilities for controlling the quality of weldment and capability to comparing the results achieved by using iQSim simulator services.

It is recommended to have in the same building welding workshop-floor and/or a material-testing laboratory as well.

The places for practical in workshop manual activities could be in a workshop of a factory etc. as well.

**Teacher’s competencies:**

He/she should

- be able to explain clearly the aim of using iQSim services as a learning tool.
- handle both forms of iQSim simulator services– internet and/or PC,
- understand the philosophy of iQSim simulator services. Namely how the different welding parameters are influencing each other and costs,
- be able to understand and explain the phenomena resulting if changing welding parameters and their effect relating to welding and weld quality.
- be able to explain to the student the results produced by iQSim simulator services and for this explanation activity using different technical, pedagogical and logical approach,
- be able to inspire the student raising questions for himself/herself which they could answer if using properly iQSim simulator services,
- be able to raise different questions related to the results of iQSim simulator services and answering and highlighting consequences.

**Structure and curriculum (time schedule/table) of course**

- The duration using iQSim simulator services during welder’s training course is about 16 hours and 3 hours for repetition and fulfilling test sheets.
  - 3 hours explanation about the idea and role of welding parameters, and student should have a common and equalized level of knowledge on welding,
  - 2 hours teacher’s demonstration of iQSim simulator services,
  - 4 hours let the students play with iQSim simulator and teacher walking round the class-room asks and observes what the students are doing,
what they are discussing among them etc., and teacher at the and
summing up,

- 7 hours home work,
- 2 hours home work presentation of students in class-room,
- 3 hours repetition – “little” – test-exam.

➢ Methodological suggestions for learning:

- the students can learn more effective if they have a methodological
  support, like this:

- dividing the learning material for home and school activities and giving
  the time necessary for both learning activities,

- the dividing learning material into modules according to “chapters” of
  iQSim simulator services, (e.g. chemical composition, join geometry,,
  technology, welding parameters, costs etc.),

- giving/nominating the tasks and tools for the students which help and
  submit the understanding, cognitive learning process e.g. students
  should preparing tasks for in class-room training hours and should
  evaluate (assess) their tasks (home-work) and later discussing it as a
  presentation in the front (before) the class-mates and this is moderated
  by the teacher,

- all modules or chapters of iQSim based task should have a
  „standardized” sign (used in the learning material), e. g.:

  ▪ sign for “easy understanding” of the task or problem,

  ▪ sign for “information only” e.g. this task should be solved
    individually (alone without help from out-side),

  ▪ sign for tasks which could be solved parallel to the teacher when
    the teacher figures out the solution and student can compare
    his/her results with the standardized teacher’s one.

  ▪ All these activities could be summarized in table, for each part
    (chapter) of iQSim simulator services, see below, like:

<table>
<thead>
<tr>
<th>Evaluation procedures</th>
<th>Part 1/ Chapter 1-name</th>
<th>Subjects belonging to Part “n”</th>
<th>Number of pages or name of file</th>
<th>Teaching hours with teacher</th>
<th>Teaching hours at home</th>
</tr>
</thead>
<tbody>
<tr>
<td>fulfilling</td>
<td>Part n/...</td>
<td>“TEST - EXAM”</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
“iQSim – project standardized check -lists” after the first (primary) demonstration of iQSim simulator services prepared for:

- students,
- teachers,

- fulfilling “iQSim – project standardized check -lists” by students after finishing iQSim- simulator services ordinary (routine) course,

- evaluation of fulfilled check-lists means feed-back of results for developing and making new type of variations if using iQSim simulator services for welder’s training,

- confirmation that the student if finished successfully the „module course for iQSim simulator services”, it means he/she will have understanding on basic interdependence phenomena of fusion welding processes.

In Hungary the welding is not popular profession and after ten years if present generation will be in age of retiring the number of welder’s community will be significant less. Therefore it is very important that the education of young generation should raise the interest and motivation for welding using “colourful” (interesting) pedagogical tools for making more and better understanding of these issues. iQSim simulator services are good for this purpose.

**ABT – Activity Based Training in Hungary**

The ABT education today could be organized in two different ways:

1/ the bigger enterprises organize ABT following their own tradition, production, industrial practices and sort of product,
2/ the welder’s training organizations prepare some typical cases similar to the activities in real industrial environment.

ad1/ The VET – activity in Hungary in the bigger enterprises producing welded structures is traditionally activity based. In these industrial units there were special places where welder’s student were trained, qualified, etc. The work was organized in such a way that students beside the theoretical lectures, and knowledge had the opportunity to exercise, making practical activity getting the necessary professional skills. In the training period of time they could learn the daily production activity of the factory. The human resource department and welding coordinator organized the ABT in the bigger enterprises.

ad2/ The welder’s training organizations have in their curriculum some programs which are similar to industrial activities.

The iQSim simulator services and ABT in this project will be coupled and having a more transparent and efficient VET- system. The technical possibility to use the information technology (IT), video streaming etc. will improve the efficiency of the
professional welding courses and will develop a strong attitude to economic and welding technology based comprehensive knowledge and activities.

The students should know and learn the real workflow and processes of the production activity from the production planning till the end when giving over the end product to the purchaser having customer satisfaction.

In the recent years the welding courses supported by MHtE organised ABT pilot training courses in four training organisations. The iQSim simulator services and ABT system are in a good and harmonised cooperation resulting good feedback.

The iQSim simulator based ABT training has the following main phases:

1. Phase is to know the product:

   - welder should know the overall and general characteristics of the product to be welded:
     - what kind of product (crane, ship etc.) should be prepared,
     - which part of it should be welded,
     - how big is the load during usage on the weld, (weld quality needed), etc.,

   - welder student should get the work package in which the following information are available:
     - technical drawing(s) of the parts to be welded,
     - work description – (so called: technological instruction) having mainly standardized structure, e.g.:
       - nomination of parts to be welded,
       - reference to drawing number and other identification data,
       - list of content of the work description, or instruction,
       - sign and name of welding technologist who made production description (the designer) and the name of inspector, approval person,
       - references for standards, guidelines, quality procedures, etc. used for planning of production and in the production process these could be used (and/or checked) by student as well,
       - determined quantities according to the requirements for parent material and welding consumables,
       - order blank to get parent (base) materials and welding consumables from store to be used,
       - determined assembly devices, and jigs and the available and verified assessed and controlled tolerances before usage,
       - preparing parts for welding: cutting (thermal, mechanical, e.g. high pressure waterjet, bending, preheating, etc.,
       - plan for welding sequences,
       - work order – with time norm for the adequate welding activity: assembly, tack-welding, welding, after welding activities, like: cleaning of weld, quality control, repair etc.,
       - WPS (according to EN ISO 15609-1),
- deadline for making the readymade weld and product,
- process slip, (this is according to the sequence of production activities),
- quality requirements, controlling equipments, handling non-conformities etc.,
- repair,
- production activity in line to the EWF -EN- ISO 9001 and EWF-EN–ISO 3834 Quality Management System,
- environment prescription with regard to the work circumstances, according to EWF-EN-ISO 14001 – Environmental Managing System,
- safety and health rules with regard to the work circumstances according to EWF -OHSAS 18001 Health and Safety managing System, etc.

**Pedagogical issues**

Beside the technical preparation work (see above) also very important that student should feel he/her is not alone when having a work task. He/she usually is acting in a special work and result oriented environment, can say, society which has prescribed and its own rules.

It is advisable to organize discussions before starting to work or making any physical activity to realize the production task - starting to get material, cutting etc. It means to seat round the table together with the teacher (or instructor) and start to study the technical drawing, discussing the main points of it, speaking about the keen points of production and asking about the solutions possible, etc. 
*The discussion should have the aim that the students(s) realize and understand the roll of the part to be produced, the difficulties to get product sound welded, etc.*

The student during ABT course should get a practice based skill to study the drawing and recognize on it where are the most difficult parts (of the work piece), where have to take care on welding activities e.g. is there enough working place for him/her to weld without difficulty, is known the characteristic problems of welding procedure used (e.g. draying of MMA electrodes, inclination angel of it during welding, etc.), and controlling the temperature between weld layer etc.

The student should get information what to do if he/her needs for his/her work some additional data e.g. going to discuss it with colleges, or going to internet, looking in standards, etc.

The main point is the student should have skills to raise welding and quality oriented/related questions, and find the adequate answers to them and have the ability to realize and control the suitability of the solution found and/or established.

*At the very end the student should on objective spiritual and professional basis aware of his/her intellectual and physical power that he/her has the ability to solve with good result any welding oriented problem on workshop floor level.*
Example for ABT:
Please prepare a mild-steel welded X-mas tree holder having the greatest diameter of 0.08 m and height of 1.8 m.

Detailed tasks are preparing:
- work-package, and verifying,
- making a real by him/her welded work-piece,
- making an adequate conformity assessment.
The situation in Sweden
The welding education in Sweden is organized in three different ways.

- Through the public school system where the (young) students may select to specialize in welding. The education and training in welding is part of the upper secondary school\(^1\).
- Through Higher Vocational Education\(^2\) at the level between upper secondary school and university organised by public and private entities financed by the government.
- Through the Swedish Public Employment Service\(^3\) as vocational education and training courses. Such courses are organized on the calculations on workforce demands.

Aim of the subject
The subject of Welding aims at providing a basic knowledge of welding, as well as the possibility of advanced knowledge in the subject. A further aim is to create an understanding of the importance of welding in different industrial activities. An additional aim is also to provide an understanding of the responsibility involved in working in accordance with national and international standards and safety regulations.

Structure and nature of the subject
The art of combining metals has been an important skill developed over a long period. Archaeologists have found soldered relics from more than 5000 years ago. The oldest method of welding steel is blacksmith welding, where the parts after heating are forged together. During the 19th century joining methods were changed. The dominant method was the use of nails. When methods for the industrial production of acetylene and oxygen were developed, gas welding could be used as a complement to nailing. Metal arc welding started to be used at the same time, but it was not until the 1930s that it was accepted in industrial manufacturing. These welding methods have, however, limited use in welding high-alloy steels and other metals in industry. For this reason new welding methods were developed, first tungsten arc welding and gas metal-arc welding and then plasma welding. Today these methods are often used and they have simplified the manufacturing of products made of special steels and other metals. Based on these basic welding methods, a large number of special methods have been developed for joining different alloys together.

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\(^1\) The Swedish National Agency for Education, http://www.skolverket.se/sb/d/353

\(^2\) The Swedish National Agency for Higher Vocational Education, http://www.yhmyndighet.se/english

\(^3\) http://www.arbetsformedlingen.se/Globalmeny/Other-languages/Languages/Engelska-English.html
In the last fifty years research into electronics and metallurgy has meant that welding power units, filler materials and welding methods have been developed and require new knowledge. The aim of mechanising welding techniques has always existed and development takes place mainly within this area today. Despite this, high demands are still imposed on workmanship in the occupation.

Sweden’s entry into the EU means that we are affected by international decisions and regulations. In the welding area, work is proceeding on creating international regulations and standards for welding constructions and their implementation. These rules are gradually replacing national rules and increasing the demand for quality thinking in all stages of manufacturing, where welding occurs. A welder, in addition to having practical experience, must also have a basic knowledge of electricity and welding technology for different materials in order to be able to live up to the requirements of the new rules. EWF (European Welding Federation) has drawn up guidelines to be applied in the training of welders. The courses in the subject of Welding are based on the EWF’s guidelines. The courses allow for flexibility in providing training in welding, which can be designed in accordance with local requirements and wishes. Pupils have the possibility of attaining the knowledge necessary for a diploma or also to get a broader preparatory education by choosing courses at the first level in different methods of welding such as e.g. A1, B1, C1 to be supplemented later.

The subject of Welding contains 22 optional courses.

The course Welding methods foundation covers the most common methods of welding and their uses and forms the basis for courses in metal arc welding, MIG/MAG and TIG welding. The course can be adapted so that competence is attained in two or three welding methods (manual metal arc welding, MIG/MAG or resistance welding).

The courses Soldering and cutting A and B cover the methods used to join and cut metals through the use of flammable gas in combination with oxygen. The courses cover the use of gas when working with and joining metals. The courses can be adapted so that competence is attained in two or three years in the methods of gas welding, gas cutting and braze welding depending on study orientation.

The courses Manual metal-arc welding A1 and A2, MIG/MAG welding A1 and A2, as well as TIG welding A1 and A2 form the basis for the competence "fillet welder" in accordance with EWF requirements in different methods. The level "Plate welder" which is a broadening and deepening of knowledge can be achieved through the courses B1 and B2 in their respective methods. The courses with a C classification deepen and further extend knowledge and provide the required foundation to work as a "Pipe welder".

These courses should be combined as follows:

Courses classified as A1 are the basis for the B1 courses. The B1 courses provide the foundation for C1 courses.
Courses with the classification B2 require knowledge corresponding to A2 and B1. The C2 courses require knowledge corresponding to B2 and C1.

The course Manual metal-arc welding C3 requires knowledge corresponding to Manual metal-arc welding C2. The course MIG/MAG welding C requires knowledge corresponding to MIG/MAG welding B2.

The course Welder competence provides opportunities to receive proof of competence in accordance with existing standards.
The situation in Lithuania

The main legal act of the Lithuanian Government is Law on Education where are described aims, principles, structure, basics and commitments of the State in the field of education.

Law on VET determines the structure of the VET system in the Republic of Lithuania, formation of qualifications, its awarding and control, organization, management, and financing of VET.

Law on Informal VET in the Republic of Lithuania regulates informal VET system of adults and gives basics of its structure, action, and management.


Formal training of welders is provided in VET schools for students older than 14 years. It takes 2 years with obligatory practical and theoretical exams. For adults welding courses usually are arranged by special Job Centres. After finishing the welder course they can be qualified welders and later can have certification, as well. Formal programmes for the welders’ training are organized in basically in two different ways.

3. Through the VET system where the young people may select to specialize in welding. The education and training in welding is part of the normal education plan for the school and takes at least 2 years.

4. Through training courses that are providing by varies institutions having right for it. Such courses are organized at certain intervals, or when they get a sufficient number of students to arrange course. Such kind training is divided into 2 levels depending on duration of training. 1st level professional qualification is awarded if duration of training is between 4 and 12 weeks. For the 2nd level professional qualification duration of training is between 12 and 43 weeks. 1st level Certificate attests person is able to pursue appropriate work. 2nd level certificate means person achieved appropriate professional qualification.

Also there are approved formal training programmes for work safety and health in Lithuania. Duration of its’ depends on work specifics and difficulty.
All formal programmes are notified in Register of training programmes. Certificates are accepted by all State and business institutions. Below are given short description of formal programmes for welders in Lithuania:

Training programme for metal arc and gas cutters and welders, code 262052104 for persons from 18 years old, duration – 18 weeks/720 h (practice training – more than 70%). The programme covers these Standards: ISO 4063-111, ISO 4063-311, gas cutting, LST EN-287-1, LST EN ISO 5817, LST EN 287-1. Certificate gives the right to work in various companies of civil building.

Training programme for arc welder, code 261052103 for persons from 18 years old, duration – 11,5 weeks/456 h (practice training – more than 70% of time). The main training is executed for getting knowledge and skills according LST EN-287-1and LST EN ISO 5817 Standards. Certificate gives the right to work in various companies of civil building.

Other 2 programmes of formal education are related to training of gas welders (code 261052102) and soldiers of copper pipelines (code 260052247).

Formal teaching of welding engineers and technologists is proposed in Vilnius Gediminas Technical University (VGTU). Duration of study programme is 4 years. Students are teaching by delivering theoretical lectures, practical calculation of the parameters of welding operations, laboratory works to familiarize welding processes, and visiting factories or enterprises producing welded metal structures. VGTU diploma is not accepted by EWF/IIW therefore graduates need to attend additional courses that are provided according to the EWF/IIW rules. In other Lithuanian engineering universities or colleges teaching of welding is a part of study programmes such as Mechanical engineering, Ship engineering, Civil building, etc. Graduates of mentioned above programmes must attend International welding engineer or technologist courses according EWF/IIW rules for performing coordination of welding of sophisticated technical subjects.

During informal training it is possible to obtain the new competency for the performing of some kind job or to improve available competency. The list of registered informal programmes for training of welding personnel in Lithuania consists of 14 programmes duration of which is 1 - 14 weeks. Informal training of welders provide special centres established by big enterprises such as large shipyards, for example, that need more welders than VET can prepare. This training is committed for adults as part of on-the-job training. People with different background and job experience can take welding course and start a new career as a welder. Very often certification of trainees in shipbuilding industry is provided by various ship classification societies. Technical supervision service of Lithuania certifies willing welding personnel from all Lithuanian industrial sectors according Standard LST EN ISO /IEC 17024.

There is not special programme for training of welding trainers today in Lithuania. Normally welding lecturers and masters have welding, mechanical or ship engineering related diploma, job experience as workers, engineers, technologist or researchers. Any pedagogical knowledge is required therefore progress in implementation of the new teaching methodology is very slow in Lithuania. The
train the trainer program gives input how to teach more effective by using welding simulator tool in parallel to teaching welding theory. Implementing of problem based learning (PBL) for welding teaching of students in schools of higher education and adults teaching during informal courses for them is crucial to not only possess technical skills and competences, but to be able to act in an application-oriented context.

Problem based learning is a student centred instructional strategy in which students collaboratively solve problems and reflect on their experiences. The philosophy of PBL is that, through the interaction between academic theory and professional practice, students develop an ability to analyse and solve complex problems in a more independent and innovative manner.

In the faculties of engineering, problem-oriented work has to be based on real life problems as much as possible. During the teaching, teachers and students together explore the possibilities of the iQSim simulator tool and try to answer “what”, “why”, and “what if” in relation to analyzing case. Teachers gradually change their traditional role and becomes facilitators in the decision making process.

The teachers and instructors: all teachers have to have higher education Master level diplomas in engineering. For teachers of IWE course is necessary EWE/IWE diplomas or doctor’s diplomas in technology or materials sciences. Welding instructors usually are experienced masters, practitioners or former welders of high qualification.

KU implemented iQSim simulator system in teaching of subject Metal cutting and welding that is obligatory for Ship engineering and Mechanical engineering students and is elective for other engineering study programmes. Also, for students of Maritime Institute Ship mechanics department, welding technologies are taught and iQSim simulator is used during Ship repair technologies course.

KU will provide more “train the trainer” courses how to use iQSim simulator after the updating of it in September and October, 2010.

The pedagogical approach

For university students and trainees of International welding engineer course iQSim simulator tool is used in class-room where is available Internet connection and PC-s. All students have to have professional literature, standards (ISO, EN and LST - Lithuanian), course books, own notes, and the programs for practical and course works. The same methodology is used for teachers’ training how to use IQSim tool in the arc welding and economy lectures.

Teacher’s competencies: understand the philosophy of iQSim simulator services; be able to explain clearly the aim of using iQSim services as a learning tool; be able to explain how the different welding parameters are influencing each other, welding quality and costs; be able to explain for students the results produced by iQSim simulator services and for this explanation activity using different technical,
pedagogical and logical approach; be able to raise different questions related to the results of iQSim simulator services and answering and highlighting consequences.

Structure and curriculum of course depends on audience background. The duration using iQSim simulator services during trainers’ training course is about 3 - 4 hours for introducing, trial solving of problems described in the prepared by iQSim partners cases, and fulfilling evaluation sheets. Normally introduction of iQSim simulator tool takes 1 hour, analysis of cases – 2 hours, and evaluation – rest of time. Training of students of International welding engineer/technologist course how to use iQSim simulator tool is organized at the same way as for trainers. Duration of the course is 4 hours and it consists of introduction (1 h), analysis of cases (2 h), discussion on advantages - disadvantages of the simulator tool and filling in evaluation forms (1 h).

Using iQSim simulator tool for teaching of welding in the Engineering faculty of university takes more time. Students have to know basics of arc welding processes, welding metallurgy, and quality management before introducing iQSim simulator tool. First demonstration of the simulator takes 1 hour. Then 1 hour teacher shows to students how to use simulator for solving of problems described in the cases. Later, students working in groups of 2-3 try to answer questions independently. At the end all presenting their results and discuss on its. For the 1st homework, students are provided with small tasks that have to be solved individually. For the course work, teacher prepares real life problems relating to production of metal constructions. Project objectives often cover all functions of personnel for welding coordination. This work has to be finished and defended till the end of the term.

During term, teaching time is gradually reducing and self-learning time is increasing. Students have to work on their problem and try to find decision how to solve it. For it, they need to attend lectures, work in the library, read books, standards and other teaching material, consult with teacher.

It was found that iQSim simulator tool brings the biggest interest while it is using time-to-time during analysis of welding parameters of different arc welding processes, influence of their value on welding quality and costs, for explanation of preparation of welding procedure specification (WPS) and analysis of WPS examples. At the end of the term, when students have enough knowledge, they can discuss on what welding process and why is more convenient from the economical or practical point of view.

Evaluation procedure consists of filling in “iQSim project standardized evaluation form after the demonstration of iQSim simulator services prepared for students and teachers. Teachers, instructors and trainees of IWE/IWT course are asked to fill in form once. Discussion during and after presentation of simulator tool, analysis of cases brings extra information and ideas for speaker. Received feedback helps developing of simulator and cases.
As teaching of welding continues all term long, students firstly are asked to fill in evaluation forms after presentation of iQSim simulator tool. Then, during the term teacher gather students' opinion by talking to them individually or in small groups.

In Lithuania, as in many European countries, welding is not popular profession. Representatives of industry talk about shortage of qualified welders, welding quality managers, and welding engineers. IQSim simulator tool helps in increasing motivation in learning so difficult multidisciplinary subject as welding. Providing of pedagogical methods how to use simulator for teaching of very different audience in point of background and job experience should help welding teachers to make subject more attractive and useful, especially for young people.
4. The iQSim Simulator Services

The 6 basic components (the 6 buttons in the top line of Fig. 4.1) of the iQSim simulator services are:

1) Defining user’s language (not shown at Fig. 4.1)
2) Defining material constants
3) Selecting geometries
4) Fine-tuning the geometry
5) Selecting welding process and welding parameters: U, I, v),
6) Displaying temperature in the Heat Affected Zone (HAZ)
7) Performing cost and economical calculations.

Figure 4.1: Sliders, which are convenient for presentations on digital blackboards, or on the screen of the PC, are used to define the V-bevel geometry.
The simulator is in its design optimized for use on digital blackboards, like the Smartboard system. By use on a PC the user will use the cursor to move the sliders and jump back and forth between the different industrial actions, whereby the same activity can be carried out on the digital Smartboard by use of the pointing device, even if it is the finger or a pen.

The services provide evaluation tools

• that include the most frequently used welding methods: MMA, TIG, FCAW and MIG/MAG

• that provide the most frequently used joint configurations or bevels: 1) Square butt (I-bevel), 2) V-bevel, 3) T joint, and 4) X-bevel.

Calculation of production costs for the four welding processes and bevel configurations above are included. The services use AIR and Flex programming solutions are prepared for presentations on digital blackboards, and all mathematical calculations are embedded into the software. The simulation and modelling part is based on simplified mathematical formulas and algorithms related to fusion welding by using operational characteristics, which correspond to good practice.

The new AIR based simulator and training solutions offer a range of new features. This includes:

• Instructors may utilize new pedagogical methodologies by including learning activities, which explore flexible easy to use on-line dynamical and/or interactive services stimulating inquiry, and problem based learning

• Students obtain new learning experiences by exploring services for application and inclusion of skills into real-world descriptions.

• The services stimulate students to dynamically play with the essential variables in order to visually understand the tolerance window that occurs in a real life production.

• The end user is offered the possibility to create alternative decision routes in real life projects. Such a tool offers the user the ability to select the technical tasks as well as the economical tasks involved in the decision process.

The simulator services contribute to the modernization of the VET system by promoting virtual simulator tools that address the technological needs in industrial training. Furthermore, it involves development of new training methodologies in combination with pedagogical sound implementation of predictive virtual welding simulators.
The “What happens if ...” approach

The iQSim simulator services are constructed in such a way that the students are “playing” with the essential variables within an industrial production framework. They investigate the influence of a number of variables in order to figure out which variable(s) that are the most important ones. That is, which variables it is critical to fix during the working process, since they may seriously alter the quality of the final results. Thus, this is different from an engineering approach where the simulator devices usually calculate numbers or fixed values. The mathematical formulas are embedded into a highly dynamic graphical user interface, whereby the focus is maintained on the variables, thus forgetting the mathematics during the simulation process. The teacher and students play with the variables dynamically by using sliders, as shown in Fig. 4.1, that create a “what happens if” scenario that maintain the curiosity element which should always be implemented in education.

The teacher may, by using the simulator services, start using questions like:

- What influences will the root gap have on the economy?
- Does tolerance in the bevel angle influence the welding costs?
- Which welding methods give the widest set of production tolerances?
- Which of the welding parameters have the most important influence on the heat input?
- Which welding parameter is the most important one, if the HAZ value is going to be maintained?

Why is this approach so important?

- The welding process always leaves the welder with alternatives. He/she may adjust the technical parameters for the process itself, for example the current could be between 160 and 200 Amps, voltage should be between 20 to 24 volt and speed between 190 to 330 mm/min.
- In such a case it is obvious that the minimum value for all variables can not be used as well as only maximum values. Something in between must be selected and then it is important to realise which parameters settings are the most favourable in the practical work. By playing with the variable a better understanding of their importance will be the result.
- In deciding the joint configuration the personnel will face the same problem. The joint is never exact as specified on a drawing. Tolerances and deviations will always occur. Before welding starts the welder must decide if he/she should start the welding process or ask for a rework of the joint. Whatever is decided here it will have economical consequences, therefore it is valuable to evaluate such consequences through the simulation process.
The training framework may utilize Activity Based Training solutions (Chapter 6). The pedagogical methods mix best practices from distance learning technologies and distance training environments. The knowledge construction follows a logic sequence that always starts from the simple to the complex. The teaching scenarios and consequences for new training methods combine the perceptive and cognitive aspects in a simulation perspective.

The iQSim simulator services provide flexible online tools that may stimulate reflective cognition processes. The students may for instance first carry out a simulation, before they verify the proposed simulation results in later practical test in the laboratory or at the shop floor. By applying such an approach the student is able to simulate the effects of selecting different welding process related parameters, and then carry out the practical welding with the same parameters. After welding test pieces can be created and both non-destructive testing, and non-destructive examination can take place in order to verify results. This may be done with the technical parameters, but also the economical aspect of the welding process may be simulated both theoretically and practically through shop welding for verification purposes.

It is several ways of implementing the simulator services in the classroom. Some examples from training scenarios are listed below:

- Answer questions targeting a calculation or “what if” type questions. The teacher uses the simulator and manipulates the variables in order to reach a conclusion. The simulator services are designed for presentations on digital blackboards, in order to utilize the interactivity of these blackboards.
- Initiate in-class reflective cognition processes. What is the most important factor for the calculation of the economy in a given welding process? The teacher uses the simulator in order to manipulate the data, and stimulate the class to reflect around the results and the effect of altering the variables.
- The teacher asks “What if” questions to the students. The students alter the variables, and must reflect around the various variables that have been manipulated during the training sequence.
- The teacher asks questions related to consequences of bad fit-up. What will be the volumes and calculations of welding costs are effective for demonstrating the consequences and effects of a certain behaviour in the production.
- The teacher may start asking questions related to consequences of selecting variables for hardness, how hardness may be verified by welding with the selected variables, followed by a hardness test in order to verify the simulation.

The simulator may be ideal as a focal point for discussions and reflections in groups, as well as for the interactive interplay during discussions between the teacher and the students. Such interplay may also include the presentation of the mathematics itself, whereby the students may better understand the consequences of physical principles and the mathematical calculations.
The material is standardized according CR ISO 15608, group 1-11 including subgroups. The ISO material grouping system should be followed. Sub groups and conventions for naming the materials follow this standard. Other data, which it is necessary to enter, should follow the same structure. This ISO standard provides minimum and maximum values for the chemical composition in the material groups. The actual material data sheets, or certificates, provided by the material supplier, may give exact chemical composition. The system should, in order to provide a possible extension of the system, store a tolerance range for the chemical composition. Thus, usually the input value is going to be the mean value of the minimum or maximum value in a process. The material composition includes: C - carbon, Si - silisium, Mn - mangan, S - sulphur, P- phosphor, Cu - cupper, Ni - nickel, Cr - chrome, Nb - niob, V - vanadium, and Ti - titanium. The material data input shall be entered with an accuracy of 2 significant figures, except for P and S, which shall have an accuracy of 3 significant figures. The Carbon equivalent, Ce, are calculated and used as a variable, from the data input.

**Preliminary Welding Procedure Specifications**

By using the simulator both for the joint configuration, V-bevel, and also for the welding process data, the teacher and the student can develop a Preliminary Welding Procedure Specification (pWPS) and document it. The next task can then be to weld a test piece and the compare the real results with the preliminary obtained data. By carrying out different simulations then multiple pWPS can be defined and later welded in the shop.

Through the interaction between the use of the simulator and practical welding, the students may observe and experience the influence of the different welding or material parameters both from a theoretical point of view as well from a practical point of view.

The student may the play with the variables and create a plan for the most efficient pWPS and discuss that within the group at the Smartbord and later prove the results in the shop.
Figure 4.2. The figure shows the welding process variables (MMA, MIG/MAG etc.), and the basic welding work parameters, which can be played with in order to evaluate the results of the variables on the heat input.

A central part of a PWPS is to figure out the number of weld layers and the heat input for each pass. The number of layers is not determined by iQSim simulator services. The correct heat input ensures a thermal balance in the weld so that the heat affected zone and the hardness is within acceptable limits. By altering the variables the students can then select the parameters that will prove most effective in practical welding and later test these parameters in the welding shop.
Figure 4.3. The figure shows the effect of the welding process variables on the economical calculations.

The economic calculation is based on the previous data sets from the joint configuration, which gives the welding volume, and the welding process, which decides the welding data set to be used for the calculation.

Based on these data the user may select some welding parameters like wire diameter, wire feed speed in this window although this could have been decided in the previous weld data set.
In the economic calculation, a simplified data model has been used for the calculation. The main reason is that a more correct model will be complicated and, for the final result, the deviation from a simplified model to a complex model is within acceptable limits, thus giving a better pedagogical understanding of the main variables for the user. Also the simplified model has been selected after discussion with industry experts from the welding industry.

Some of the major cost factors will be labour costs, duty cycle, deposition rate, repair percent and repair costs. For the repair costs is meant that the total cost for a repair shall be used, which are:

- grinding and gauging costs
- costs of re-weld including rigging of equipment for that purpose
- costs of new control and documentation of the repair

The main reason for adding this to the welding cost is to focus of the consequences of a repair and at the same time highlight the value of doing the weld right from the beginning.

The calculation data sheet has a number of intermediate results, highlighting the costs of the different elements.

A sound discussion with the students will be to calculate the costs, then go back and alter some of the joint data and then go back to the calculation data sheet in order to observe the influence on the costs.
Material composition versus hardness and cooling rate
Actually three different scenarios can be used based on the chemical composition.

1. Calculate different values like Ce and so forth and then alter the value of the chemical elements in order to study their influence on these values.
2. To combine the chemical composition with the window for the hardness. Through interactions between these two windows the student can evaluate the chemical components influence on the HAZ, the size of the HAZ and the cooling time.
3. To combine the previous two windows with the window for the welding parameters. Through this the heat input generated through the arc itself can be evaluated in combination with the chemical properties. Again these combinations can strengthen the knowledge of material science and heat input.

Figure 4.4: The window for evaluation of chemical composition.
Figure 4.5: The window for evaluation of the welding parameters

Figure 4.6: The window for showing the result on HAZ and temperature curves based on the two previous windows. The relations is clearly shown and moving back and forth between the windows gives a dynamically result on the users preferences.
Welding geometry versus welding costs.

By evaluating the welding geometry itself a number of interesting scenarios may be discussed.

1. What is the influence of alterations of the weld geometry for the weight of the weld metal per meter weld?
2. What is the influence of the weld quality on the weld metal requirements?
3. What is the influence of the two scenarios above on the cost per meter weld?

These simulations are essential for understanding of the consequences of creating a product with the right quality. It also focus on an ongoing discussion of the responsibility of welding personnel and their need to act if the specified tolerances and quality on the product details itself, are not according the specification.

Figure 4.7: The window for specifying the weld joint details.
Figure 4.8: The window for specifying the welding costs

By moving between the two windows, geometry and welding costs, a dynamically alteration of the costs will occur when the geometry data are altered, thus highlighting their relations.

Welding parameters versus heat input.

A central variable for the welder is the heat input. In all welding documents like WPS, the essential welding data are specified with a tolerance window or a range where the welder has to adjust his/her parameters so they are within the specified range. However as a combination of the parameters can work in different directions, it is essential that the heat input is within the specified range.
Figure 4.9: The window for simulation of welding parameters.

It is also important to notice that also ambient temperature and preheating have been added as variables here.
5. Teacher use cases

The simulator is ideal as a focal point for discussions and reflections in groups, as well as for the interactive interplay during discussions between the teacher and the students. Such interplay may also include the presentation of the mathematics itself, whereby the students may better understand the consequences of physical principles and the mathematical calculations.

A number of user cases from industrial production have been developed in order to use relevant problem-based training scenarios. They can be used stand-alone in such a way that the teacher demonstrate the tasks and effects on a Smartboard, by demonstrating what is done or he/she ask the students about what to do in the next steps. Through the interactive communication with the students they find a solution and conclude on how to fix the physical parameters. Alternatively, the cases may also be presented to the group of students, or as individual tasks for each student, whereby the students can reflect around the problem and try to figure out a possible solution.

The use of the simulator is essential in understanding a specific user case. It is mandatory to let the students reflect around the possible causes for a problem, and then suggest a possible explanation or solution to the problem. The starting point is the work orders that are used in industrial fabrication processes.

The interplay between theoretical reflections and discussions and the verification of the discussions through practical welding in the shop let the students learn the interrelations between essential process parameters and their importance for the practical work.

The combination of technical simulations with economical analyses has been an important factor during the education process. Instead of only focusing on the technical topics, the students have to discuss the economical consequences of their decisions when developing a preliminary Welding Procedure Specification (pWPS).

In the field of welding fabrication, the EN ISO 3834 Quality requirements for fusion welding of metallic materials is an application specific standard for welding, and serves as a reference for ISO 9000 standards. The EN ISO 9000 series of standards may serve as a competent and specialized path designed to cope with all mercantile and regulatory requirements that implicitly are given by the directives and product standards. Such a scheme includes requirements for certification and updates of personnel certificates and diplomas in a welding production environment.

Teacher use cases for education of welders

The following use cases have been developed for the use of iQSim simulator services in the education of welders.
**Use case 1 (NO)**

The student has got completed WPS, as specified in figure 5.1, where the material has been specified with a given CE max value. When the material has been delivered with a material certificate, the CE value must be verified. However, through the simulation it turns out the CE value is exceeding the max value in the WPS.

Figure 5.1: The WPS data has been given for a fillet weld. The CE value is important for this job and the given value cannot be exceeded.

The student shall discuss the following topics:

- What has been the main factor for creating an exceeded CE value?
- What does the alteration in the CE value mean for the weldability?
• Does the alteration in the CE value have any influence for the hardness?
• What is the practical consequence of the problem?

Use case 2 (NO)
The student has got an WPS, Fig. 5.2, where the joint configuration has been specified with a root opening with 0 – 2.0 mm. Material thickness is 20 mm, v-bevel, nose 1-2 mm. However when the welding of the assembly shall start then it turn out that the assembly has been tack welded with a root opening of 4mm.

Figure 5.2: The WPS has requirements for the geometrical dimensions. However after tack welding it turns out that these dimensions are not met. Evaluate the consequences.

The student shall discuss the following topics:
• What are the consequences if you are welding this joint?
• If the weld length is 450 meters, what does this mean in costs and welding time?
• What shall be done – cut the tack welds and reassemble?

**Use case 3 (NO)**

The student has got a WPS for a V-bevel joint and material thickness 20 mm, Fig. 5.3. The student must cut the plates according to the drawing specification. Let the student do that job and then measure the joint configuration and let them report the findings of the teacher. Afterwards discuss the possible deviation they have on the material compared with the drawings and let them use the simulator to observe the consequences for the production.

Figure 5.3: A WPS with a given set of geometrical tolerances, which shall be met.

The student shall discuss the following topics:

• What was the finding in tolerances
• What do these tolerances result in welding time?
• What do these tolerances mean in costs?

Use case 4 (NO)
The student has got a WPS with a fillet weld with a plate thickness of 10 mm and throat thickness 5 mm, Fig. 4.4. Weld length is 800 meters. When visual inspection is carried out then it shows that the throat thickness is 7 mm.

Figure 5.4: A WPS for fillet weld where plate thickness shall be 10 mm and a = 5 mm.
The student shall discuss the following topics:

• What is the consequence of use 6 mm throat thickness?
• What was the result in welding time?
• What is the results in welding costs

Use case 5 (NO)
The student has got a WPS where the hardness requirements has been stated not to be more than 285 HV10. This is due to the fracture mechanics for the structure. The student shall discuss the following topics:
  • Which welding parameters gives the welder the most freedom for variation?
  • Which welding parameters will you keep fixed as much as possible?

Use case 6 (NO)
The student receives a WPS, Fig. 4.5, where the diameter of filler can be varied from 2.5 to 3.25 mm. The student shall discuss the following topics:
  • What are the consequences of selecting one or the other filler diameter?
Figure 5.5: The electrode diameter can vary from 2.5 mm to 5 mm. Evaluate the consequences of selecting the different type of electrodes.

Use case 7 (NO)

Let the student receive a WPS with an X-bevel, 35 mm plate. When the parts arrive then it turns out that the nose is 2 mm shorter than prescribed.

The student shall discuss the following topics:

- What are the consequences of the shorter nose?
- In welding time?
- In costs?
• If the total weld length is 300 meters what shall then be done?

Use case 8 (NO)
The student gets a WPS, Fig. 4.6, with a set of welding parameters. Let the student play with the welding parameters and then view the consequences for the temperature curves.

Figure 5.6: A WPS with a given set of welding parameters and preheat requirements
The student shall discuss the following topics:

- Which welding parameters are influencing the temperature curve mostly and why?

Switch the temperature curve for the welded material on and measure the temperature 5 mm deep into the material.

- What are the consequences for the temperature in the material?

Discuss the result of the simulation in view of possible heat distortion.

- What are the possible consequences for the structure?

Use case 9 (NO)
For a repair weld the welder may select alternative electrodes for the repair. Repair length is 20 meter. The main welding parameters are as follows: 160 A, 24 V and 120 mm/min welding speed.

The student shall discuss the following topics:

- Which electrode do you want to use?
- Why do you select that electrode diameter?
- What are the consequences of your selection?

Use case 10 (NO)

Figure 5.7: Material certificate from ESAB.
The student has received a material certificate covering the material, which shall be welded.

- Calculate the CE and PCM values for this certificate
- Can you use this plate if you are going to use the WPS given in Figure 5.7?

**Use case 11 (NO)**
The student should get the following task:

- Select a material
- Select a welding process and choose a set of welding parameters for that welding method, including ambient temperature (material temperature) and preheat.
- Go to the HAZ calculation and observe the HAZ value and cooling time.

The following questions could be asked:

1. Which of the welding parameters have the strongest influence on HAZ?
2. What influence do ambient temperature and preheat have on the HAZ?

When these questions are answered and then move back to the material selection, and ask the students to alter the carbon content and other chemical components.

The following questions can then be asked:

- What are the most important chemical element for the HAZ calculation?
- How are the alteration in chemical composition compared with the welding parameters?
- What are the consequences of these results for a real life production situation?

**Use case 12 (SE)**

**Pressure container**

A pressure container in wedox 900 d has burst in some places in the heat zone. The cracks should be addressed.

Select additive material, method and approach.
Use case 13 (SE)
Pressure container

On a pressure container is a $\frac{1}{2}$ sleeve to be welded for an indicator. The pressure container is made of 2912 and 5 mm in thickness.

Select additive material and method.
Use case 14 (SE)
A tank with a width of 20 meters and a height of 10 meters will be built. The plates are rolled and ready for welding.

<table>
<thead>
<tr>
<th>Material</th>
<th>Width</th>
<th>Height</th>
<th>Thickness</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>2343</td>
<td>2000</td>
<td>*</td>
<td>1000</td>
<td>* 5.</td>
</tr>
<tr>
<td>2343</td>
<td>2000</td>
<td>*</td>
<td>1000</td>
<td>* 2.</td>
</tr>
</tbody>
</table>

Describe the likely approach, methodology and additive material.

![Image](image.png)

Figure 5.10: Production of a thank

Use case 15 (HU)
Provided by MHTE ....

Please answer which welding parameter of U, I, v can influence in a larger scale the productivity of welding if parent-material, weld geometry and welding process are constant and explain the reason of the phenomena?

Use case 16 (HU)
Provided by MHTE ....

Please answer the effect of the ambient temperature on the cooling time and hardness in HAZ if this temperature is changing from 0°C to -35°C, and if all other figures remain the same?
Use case 17 (HU)
Provided by MHtE ....

Please determined the different features of welded joint characteristics if diameter of welding wire electrode will be changed from 1,0 ; to 1,2 mm and all other figures will remain the same.
Teacher use cases for welding engineer or welding designer education

These use cases are intended for use in an engineering environment, either as welding engineer or as a weld designer. It is assumed that these personnel categories have adequate mathematical background to calculate the correct answers for the use cases. However the use cases are here used for discussion and reflections around general problems and topics, which are regarded as general.

Use case E1 (NO)

In a deck structure the stiffeners will be welded by fillet weld. The deck plate is 8 mm and the stiffener is 12 mm. Total weld length is 850 meters. The welding engineer has selected two WPS which can be used for this job: E13 Bas (Fig. E5.1)
Figure E5.1. The fillet weld WPS has been specified as one alternative.

or E1 Test (Fig. E5.2)

The student shall discuss the following topics:

- Which WPS shall be used?
• What is the consequences of using the selected WPS compared with the other?

Use case E2 (NO)
The student has received the material certificate S-2522.

Figure E5.3: Material Certificate S-2522
The following tasks must be answered:

- Calculate the CE and PCM values for a given plate between pos 16 to 26.
- Explain the main differences between the CE calculation and Ceiw calculation
- When will you select the CE calculation versus the Ceiw calculation?

**Use case E3 (NO)**
The student creates a calculation of CEIIw.

The following tasks have to be answered: Explain the difference from CEIIw and Cen. When shall the different CE values be used

**Use case E4 (LT)**
Manufacturing of mini panel in the shipyard:

Welding of T-joints (total length is 50 m) by using FCAW process (136):

Steel S355, thickness $s_I=6$ mm; $s_{II}=10$ mm

Wire diameter $d_w=1.2$ mm

Current $I=280\pm10$ A

Voltage $U=27\pm1$ V

Welding speed $v_s=35-45$ m/min

Speed of wire $v_w=8-10$ m/min

The student shall discuss the following topics:

- How will change the price of welding if welder produce mini panel with $a=3$ mm, 4 mm or 5 mm?
- What impact for welding price has change of $v_s$ and $v_w$ if welder welds $a=3$ mm?
Use case E5 (LT)

Manufacturing of mini panel in the shipyard:

Welding of T-joints (total length is 80 m) from S355 (thickness s_I=6mm; s_{II}=10 mm – see previous picture) by using MAG (135) process:

Wire diameter \( d_e = 1.2 \) or 1.0mm

Current \( I = 310 \) A

Voltage \( U = 30 \) V

Welding speed \( v_s = 40 \)m/min

Speed of wire \( v_w = 10-12 \)m/min

The student shall discuss the following topics:

- What is the price of welding if welder is producing mini panel with \( a = 3 \)mm or 4 mm?

- Compare these prices to the price when mini panel is welded by using MMA (111) process:

Electrode diameter \( d_e = 4 \) mm

Current \( I = 170 \)A

Voltage \( U = 23 \)V

Welding speed \( v_s = 10-15 \) cm/min
6. Various iQSim Pedagogical Methods

The iQSim simulator services have been designed for use in combination with various pedagogical methods. In the following sections, several types of training methods that utilize the simulator services are described.

A number of use cases and tasks have been developed based on practical industrial production in order to use relevant problem-based training scenarios. They can be used stand-alone in such a way that the teacher demonstrate the tasks and effects on a Smartboard, by demonstrating what is done. Or he/she asks the students about what to do in the next steps. Through the communication with and between the students they have to find a solution and agree upon the physical parameters to be used. Alternatively, the cases may also be presented to group of students, or as individual tasks for each student, whereby the students can reflect around the problem and try to figure out a possible solution.

The use of the simulator is essential in understanding a specific user case. It is mandatory to let the students reflect around the possible causes for a problem, and then suggest a possible explanation or solution to the problem. The possible explanation may also be found in the practical exercise in the shop when the agreed pWPS’s are welded and later tested.

The interplay between theoretical reflections and discussions and the verification of the discussions through practical welding in the shop let the students learn the interrelations between essential process parameters and their importance for the practical work.

The combination of technical simulations with economical analyses has been an important factor during the education process. Instead of only focusing on the technical topics, the students have to discuss the economical consequences of their decisions when developing a pWPS.

Activity Based Training (ABT)

Vocational training models must offer support for integration of interactive learning and training styles into distance training practices. Inclusion of blended learning training principles requires special attention towards exploitation of digital video case libraries, videoconferencing and integrated technical solutions that may forward training to groups of students within one educational environment. This includes transfer of two parallel video streams displaying both the teacher and the presentation.

ABT targets especially the needs for certification based training processes and transfer of competence to personnel working in the mechanical industry sector. The ABT pedagogical practices facilitate.

- a just-in-time on-the-job production workflow competence and knowledge transfer approach
• a sound pedagogical model where theoretical training is always immediately followed by practical training
• coordinated use of advanced video technology
• promotion of industrial quality assurance management designs processes where students exchange their products several times during a course.

A typical mechanical industry fabrication process utilizing welding is often given as a work order which is divided into a number of work packages. A work package is a detailed and sequential description of the working task that is going to be done and it is normally divided into one or several activities. Delivery of the final welded product requires a number of steps from fetching the material, through cutting it into smaller pieces, which will be assembled and welded to a new product. These sequential activities will contain both theoretical and practical tasks, which also include quality assurance and quality control of the job itself. The work package contains at least the following task information in order to secure that the process can meet the required quality:

- Work drawing(s) showing the structure of the final fabricated object, i.e. specific details and information for the tasks.
- Work description(s) covering how to do the job and which methods that are going to be used in the production. This includes work process description(s) containing the pre required knowledge, the working processes needed in order to produce the final product, and work package description(s) covering all the work that is going to be done.
- Quality requirements for the product to be produced and delivered. This includes quality assurance requirements for the ingoing elements, and quality assurance descriptions and requirements for the outgoing elements.

**How to construct work orders**

It is a core idea of ABT that the student during the training activities produces a product, by going through an industrial production process that consists of a number of steps that may be identified and treated as standalone elements if required.

Thus, instead of utilizing the traditional methodology whereby the student moves through a traditional education with theoretical content from A to Z, followed by hands on training, it is possible to use ABT. With ATB it is understood that the training follow the production activities according the production path of a predefined structure or product. However an ABT course can also be developed related to a range of services as well. This may for instance include banking activities, travelling activities, health activities and so forth. It is recommended to use and exploit a blended approach whereby different delivery technologies for the content itself are used.
The course here has been divided into 9 different modules and three of these are modules where the major part of the hours will be utilized for practical work. This means that the students have to participate together in a workshop or laboratory.

This is an important aspect of the methodology itself. When working in an industrial environment the student has to work together with other personnel in order to meet the requirements in quality, time schedules and so forth. The team building effort, its importance for the final product and its importance for the total quality of the production environment must be stressed during the educational process.

In a welding environment today the students will work together with other persons from different cultures, with different educational backgrounds and with different practical experience, which will require a profound focus on flexibility and open-minded attitude towards other people. Few if any other educational routes will demand such flexibility to the student itself and to the student’s behaviour on a short and long term basis.

Figure 6.1: The course will consist of several job-elements or modules. The figure shows how a work-package may be built up and consists of different modules, some are pure theory modules, while other are a mixture of theory and hands-on training. The training will be carried out in the workshop, shop, or in a laboratory. Video streaming and/or videoconferencing may be used in Shop/Theory packages.

A work package may contain several elements. They are usually developed with basis of an order or a contract, which describes the product and the conditions for delivering it. A work order must be prepared as the basis for the education and training activities, as well as for planning learning activities. One central and essential element is a complete documentation package, which specifies activities
that must be mastered in the welding industry in order to handle the whole production process. It contains at least the following information:

- Drawing of the structure to be fabricated
- Work specification with which methods shall be used in the production
- Delivery requirement with process description of the work process for reaching the target, the knowledge required and the delivery time schedule
- Quality requirements for the delivered product
- Quality assurance specifications
- Work package description for the work to be done
- Reference to available resources for the work
- Reference to environmental resources or requirements or restrictions
- Reference to specifications and standards
- Cooperation strategy with other in a defined group or to related groups

However, the production staff must master some basic prerequisite knowledge in order to follow the knowledge requirements. The knowledge and competence requirements include:

- Ability to work in a multicultural environment with the colleagues due to exchange of mobile personnel across borders and among mechanical industry companies
- Ability to understand and communicate the content in the job packages to the colleagues in a multilingual working environment
- Ability to understand his/her responsibility in the production chain and to communicate the need for knowledge.
- Ability to search for relevant learning and training material when needed.
- To understand how a process plan might be visualized in combination with a project plan.

A central philosophy within fabrication is that the person who produces a product shall not be the one carrying out the quality control of the same product. To establish the same mythology in education one aims at introducing an alternative production flow whereby the product alternate between students or student groups.

Collaborative learning is described in (B. Harrison) as: “Collaborative learning is based on learning through personal or social interaction amongst students. It is designed to help students to share goals, exploit learning materials and achieve deeper levels of understanding and knowledge built by the social construction of meanings and knowledge. Students work collaboratively or cooperatively in teams in order to carry out the tasks. In this environment, students are free to make mistakes when learning because their peers are not competitive, but rather cooperative and collaborative. This type of environment is similar to a real community.
The pedagogical perspective is based on learning through personal or social interaction with priorities and targets. A collaborative learning process can help students to share goals, exploit and to be able to decide on the best working methods, especially when an individual has a poor learning materials and need to achieve deeper levels of understanding and knowledge.

Collaborative learning is particularly useful to develop social skills such as respect for others, tolerance and team work, elements which are highly required in the daily work. This model will be used for the courses developed through an ABT based course.”

The activities foreseen in a typical ABT course will consists of using a number of modules and teaching processes mixing onsite and e-learning training solutions. ABT training tasks and activities are structured with respect of the delivery plan and the production process of the final product. Designing an activity plan as demonstrated in Table 6.1 may at the practical level do this. Table 6.1 shows how this may be done in a course of welding of stainless steel.

<table>
<thead>
<tr>
<th>Process no</th>
<th>Module no</th>
<th>Name/Topic</th>
<th>Purpose</th>
<th>Description for teachers and instructors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>Introduction to the course: Stainless Steel</td>
<td>Introduction to the course, and the expected knowledge obtained after completion of the course.</td>
<td>This shall be a general introduction that shall highlight the course content and scope. Direct link to a video introduction is preferable. Presentation of the product that is going to be produced during the course.</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>Student Groups</td>
<td>Establish student groups, and create smaller subgroups for later parallel activities.</td>
<td>The teacher either create one group or divide this group into smaller units in case these units later shall work with parallel activities and get different roles in the production.</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>Work Package</td>
<td>Introduction to this course module. The introduction specifies the scope of the module, and the expected knowledge obtained after completion of the module.</td>
<td>A standard introduction is used, or it is modified by the teacher or created from scratch by the teacher.</td>
</tr>
<tr>
<td>Process no</td>
<td>Module no</td>
<td>Name/Topic</td>
<td>Purpose</td>
<td>Description for teachers and instructors</td>
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<td>-------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>Work Package Resources</td>
<td>The teacher adds the educational learning material.</td>
<td>This is a multi task activity where the students in addition are asked to discuss the topic Work Package. The teacher can add more topics. Simulator can be used for cost simulation purposes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>A standard set of resources according to the requirements in the Guidelines is added.</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>Start of training activities</td>
<td>Introduction to this course module. The introduction specifies the scope of the module and the expected knowledge obtained after completion of the module.</td>
<td>A standard introduction is used, or it is modified by the teacher or created from scratch by the teacher. Simulator can be used for cost bevel preparation purposes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>Resources</td>
<td>The teacher adds the educational material.</td>
<td>NOTE: If the course is run with students accessing the course material through Internet, it must be decided how the student should be able to upload his/her own learning resources into the course material. Using platforms like MOODLE could do this.</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td>A standard set of resources according to the requirements in the Guideline is added.</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>4</td>
<td>Cutting</td>
<td>Introduction to this course module. The introduction specifies the scope of the module and the expected knowledge obtained after completion of the module.</td>
<td>A standard introduction is used or it is modified by the teacher or created from scratch by the teacher. Since this topic may cover many cutting methods, also methods that are not available at the educational institution, it is foreseen that the introduction could be accomplished with video material.</td>
</tr>
<tr>
<td>Process no</td>
<td>Module no</td>
<td>Name/Topic</td>
<td>Purpose</td>
<td>Description for teachers and instructors</td>
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<tr>
<td>8</td>
<td>4</td>
<td>Cutting Resources</td>
<td>The teacher adds educational resources. A standard set of resources according to the requirements in the Guideline is added.</td>
<td>This is a multi task activity where the students in addition are asked to discuss different aspect around the cutting process. Of special importance are the Health, Environment and Safety aspects as well as the quality aspects. Since this is the first practical stage in production it is important to discuss the process flow and the quality aspect of each step in this flow.</td>
</tr>
<tr>
<td>9</td>
<td>4</td>
<td>Cutting, Quality Report</td>
<td>To generate a quality report for the components the students have produced.</td>
<td>If the students are split into different groups, then these groups may audit and verify the work provided by other groups. A student should not verify his/her own work. Simulator can be used for verification of joints and its consequences for the cost.</td>
</tr>
<tr>
<td>10</td>
<td>5</td>
<td>WPS</td>
<td>Introduction to this course module. The introduction specifies the scope of the module and the expected knowledge obtained after completion of the module.</td>
<td>A standard introduction is used, or it is modified by the teacher or created from scratch by the teacher. Simulator can be used for heat input simulation and HAZ.</td>
</tr>
<tr>
<td>11</td>
<td>5</td>
<td>WPS, Resources</td>
<td>The teacher adds the educational resources. A standard set of resources according to the requirements in the Guideline is added.</td>
<td>A set of WPS's must be available in order to allow the student to select the correct WPS in the forthcoming welding process. This is a multi task activity where the students in addition are stimulated to discuss different aspect around the use of WPS, and</td>
</tr>
<tr>
<td>Process no</td>
<td>Module no</td>
<td>Name/Topic</td>
<td>Purpose</td>
<td>Description for teachers and instructors</td>
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<td>why the WPS is important as a production document.</td>
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</tr>
<tr>
<td>12</td>
<td>6</td>
<td>Assembly</td>
<td>Introduction to this course module. The introduction specifies the scope of the module and the expected knowledge obtained after completion of the module.</td>
<td>A standard introduction is used, or it is modified by the teacher or created from scratch by the teacher.</td>
</tr>
<tr>
<td>13</td>
<td>6</td>
<td>Assembly, Resources</td>
<td>The teacher adds the educational resources. A standard set of resources according the requirements of the Guideline will be added.</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>6</td>
<td>Assembly, Question and Answers</td>
<td>Questions for the students to be defined by the teacher. The student has to submit a written answer.</td>
<td>It is assumed that some key questions should be raised at this stage before tack welding occurs. The parts have to be assembled in a fixture or by help of other tools. Questions related to these topics could be raised. However, the questions will most probably dependent of the product that is going to be welded and should therefore be tailored to the course itself.</td>
</tr>
<tr>
<td>15</td>
<td>7</td>
<td>Tack Welding</td>
<td>Introduction to this course module. The introduction specifies the scope of the module and the expected knowledge obtained after completion of the module.</td>
<td>A standard introduction is used or it is modified by the teacher or created from scratch by the teacher.</td>
</tr>
<tr>
<td>Process no</td>
<td>Module no</td>
<td>Name/Topic</td>
<td>Purpose</td>
<td>Description for teachers and instructors</td>
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</tr>
<tr>
<td>16</td>
<td>7</td>
<td>Tack Welding Resources</td>
<td>The teacher adds the educational resources.</td>
<td>Simulator can be used for planning of welding parameters.</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td>A standard set of resources according the requirements in the Guideline is added.</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>8</td>
<td>Welding</td>
<td>Introduction to this course module. The introduction specifies the scope of the module and the expected knowledge obtained after completion of the module.</td>
<td>A standard introduction is used, or it is modified by the teacher or created from scratch by the teacher.</td>
</tr>
<tr>
<td>18</td>
<td>8</td>
<td>Welding Resources and Forum</td>
<td>The teacher adds the educational resources. A standard set of resources according the requirements in the Guideline is added.</td>
<td>This is a multi task activity including a discussion forum. The idea is that the students shall discuss some of the key questions related to the welding process itself before they move into the workshop for practical welding. These questions can be a mixture of standard questions as well as product related questions. It is foreseen that also the process and the impact of the welding for the quality and quality related topics are discussed before welding.</td>
</tr>
<tr>
<td>19</td>
<td>8</td>
<td>Welding, Question and Answer, Journal</td>
<td>Activity to be carried out after the welding has taken place. The activity consists of two steps; question and quality related issues.</td>
<td>The activity is aimed as a preliminary control activity of ones work. This could however be taken as a two-step process. First, the students own control and verification of own work and another student could do the same activity on the same object. By</td>
</tr>
<tr>
<td>Process no</td>
<td>Module no</td>
<td>Name/Topic</td>
<td>Purpose</td>
<td>Description for teachers and instructors</td>
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<td>doing so one would assure that the part is verified by an independent source. Simulator can be used for verification of actual welding parameters.</td>
</tr>
<tr>
<td>20 9</td>
<td>Qualification</td>
<td>Introduction to this course module. The introduction specifies the scope of the module and the expected knowledge obtained after completion of the module.</td>
<td>A standard introduction is used or it is modified by the teacher or created from scratch by the teacher. This activity is added in order to learn more about the personnel qualification, certifications and education paths that can be followed in welding technology.</td>
<td></td>
</tr>
<tr>
<td>21 9</td>
<td>Qualification Resources</td>
<td>The teacher adds the educational resources. A standard set of resources according the requirements in the Guideline is added.</td>
<td>Reference to standards and EWF Guidelines or other national guidelines for personnel training must be added.</td>
<td></td>
</tr>
<tr>
<td>22 10</td>
<td>Delivery</td>
<td>Introduction to this course module. The introduction specifies the scope of the module and the expected knowledge obtained after completion of the module.</td>
<td>A standard introduction is used, or it is modified by the teacher or created from scratch by the teacher. It is assumed that the product produced in the course is going to be delivered to a customer, e.g. another student as a “buyer”. This means that the product must be properly documented and has gone through a delivery routine with adequate quality assurance.</td>
<td></td>
</tr>
<tr>
<td>23 10</td>
<td>Delivery</td>
<td>The teacher adds the</td>
<td></td>
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</tr>
</tbody>
</table>
Table 6.1 Outline of the activities in an ABT course for welding for stainless steel.

The theoretical training is delivered when needed according to the production schedule. It should be noticed that the content, as described and specified by international guideline, is maintained by this system. However, the delivery of the content is adapted to the practical production tasks and training. Thus, by organizing it in this way, we achieve the following:

- Theory is delivered just in front of practical training sessions
- Theory becomes relevant for the training activities that are going to be done
- A direct link between theory and practice is established
- The student needs the theory in order to carry out the training task itself

**Digital blackboard tools**

A set of visual communication and collaboration tools may be used in an ABT course. Short and targeted video streaming clips focus on a specific task or production process problems that may easily be directly related to practical training tasks. The blended mixture of video clips demonstrates how to do, and how not to do. This ensures that students may observe a problem and reflect around possible solutions and corrective actions. Afterwards, they may test it out in real life after the reflection period.

A Smartboard is a digital blackboard that is used together with a PC, as a visualization tool. It may be utilized for distance learning by combining it with a video conferencing system. The Smartboard is used as a traditional blackboard, but since it is electronic a number of additional functionalities are available for the instructor. The teacher develops slides that look like PowerPoint type presentation. The instructor may comment on each PowerPoint through by using digital pens, as well as inserting new slides with or without text, move, scale, rotate the slides, insert
pictures and manipulate these, insert drawings or part of a drawing and comment on the drawing. The instructor may store the result of the manipulations, (adding text, comments, pictures and so forth) as a standard file in HTML or PDF.

These features are important in learning and training environments where the instructor activities use a large amount of complex drawings, pictures and possible video clips. The Smartboard organizes the multimedia material and displays it in a convenient way for the instructor.
Embedded into the instruction process

The approach was to make the simulator tool become an embedded part of the learning method by linking the various parts of the simulator to the syllabus. By doing so, the students get the opportunity to test the “what if” possibility of the simulator and by that get a deeper understanding by the visualisation of the welding process.

The using of the simulator starts with an introduction of the iQSim simulator tool to demonstrate the abilities and functions. After the introduction, when the students had familiarised them self with the tool, the teaching continues with the education activity according to the syllabus. When suitable, the teacher gives the students an opportunity to test what happens if they change different parameters, linked to the current review, and by that resave a eminently visual feedback on there actions.

Problem based training

Students weld test pieces based up on use of services, and compare with results from simulator services. The problem-based training in this case has three phases:

It’s so much easier to suggest solutions when you don’t know too much about the problem. Malcolm Forbes (B. Harrison)

“What is Problem-Based Learning (PBL) ? (M. Kiley et. al)

The amount of knowledge is increasing and the rate at which it is increasing is accelerating. Students cannot learn all the material, but they can learn how to learn the material. This is an important step in helping students become self-directed learners. In the problem-based learning students learn to be self-directed, independent and interdependent learners motivated to solve a problem.

Students learn independently research and gather information that confirms or disconfirms their hypotheses and generates new understandings. These new understandings are presented to the group, which then considers all the information brought in by its members.

This may be:

- new formulation of the problem,
- additional information being added by the tutor,
- the identification of questions and information needed to discriminate between competing hypotheses or explanations.

Finally the students and tutor assess the quality of the answers they’ve obtained, as well the effectiveness of the processes used.

PBL is a curriculum development and instructional method that places the student in an active role as a problem-solver confronted with ill-structured, real-life problems.
It is most commonly characterized by five facets:

- well-structured problem,
- real life significance,
- student-led,
- instructor facilitated,
- community focused.

PBL is used from early elementary education through the university level and beyond.

Training organizations have been moving from static, teacher-centered means of instruction toward more student-focused means of transferring the learning of concepts to their students. One of the goals of this move are to create training that causes a “need to learn” on behalf of the student. Another is the delivery of education that allows the student to practice and refine traits and skills they will use in the real world. Problem solving approaches, such as the case study method and Problem-Based Learning (PBL) are two ways an instructor could structure their class experience to address similar objectives.

PBL can be used to describe a variety of approaches to instruction, all of which share the common trait that they anchor much of the learning and instruction in “concrete problems” for students to analyze and resolve.

In studies assessing the effectiveness of PBL, researchers found students, immediately after PBL processes, did significantly poorer on immediate multiple choice tests. Six months later, though, these same PBL students demonstrated a recall of concepts up to five times higher than the traditionally-instructed groups. Certainly, this leads one to ponder what “success” might mean in an adult learning setting.

PBL is consistent with the tenets of active adult learning. Its emphasis on self-directed learning means students must engage and move through learning with a high degree of accountability. It also means the planning and managing aspects of instruction may have a greater portion of the teacher’s time.

General steps to follow are:

- identify, consistent with the learning objectives of your lesson or topic, potential “problems” for work in the class setting
- brainstorm a possible “problem” that will illuminate the concept within that application or setting
- select at least one “real-world” application or setting for that concept
- ensure the problem scope and focus is conformed to the scope and nature of effective PBL problems as described below
• further develop one problem for the envisioned class.”

The PBL cycle:

1/ the problem,
2/ what do’nt we know,
3/ learn what we do’nt know,
4/ apply this knowledge.

The role of tutor is:
- clarifying discussion (e.g. “what are the two different perspectives we are talking about here?),
- suggesting avenues of investigation,
- putting a problem in context,
- prioritising issues.

Steps in developing a problem:

1/ developing objectives,
2/ formulating problems,
3/ combining problems,
4/ providing resources

Assessment:

Key questions to ask are:

a/ how do I assess course knowledge?
b/ how do I assess skills?
c/ how do I assess attitudes?

Steps in assessment:

1/ define objectives,
2/ decide on assessment instruments,
3/ define criteria and marking system

Evaluation:

The evaluation types of curriculum:

- outcome evaluation looks at the qualities the PBL course engenders in students,
- process evaluation considers what happens during the learning/teaching process and examines the course in its operation.

Steps of evaluation are:

1/ select what it is you want to evaluate,
2/ select the most appropriate strategy for evaluation,
3/ analyse the results,
4/ provide feedback and propose action

How to solve a problem if using ABT method and iQSim – welding simulator:

Let see the problem:

_In the market there is a need for a washing machine having long life cycle revolving drum, before starting the serial production it is decided to produce a prototype welded construction to establish the welding parameters, the work piece should have a conformity certificate based on testing._

Before starting to solve the problem it is advisable to survey some related ideas and use the general concept for solving reality like problem, similar as it is detailed below (but you can have your own system as well.

If you choose the method advised please define your activities in details as listed below: (Kirkly et al.):

1/ prepare the mission, action goals of your activities which ends up having an excellent revolving drum,
2/ action plan (detailed problem solving approach, basic resources, expert guidance, performance supports e.g. tools, jigs, check lists, individualized guidance), not forget your established mission,
3/ implementation (using what you have learnt, or your knowledge if researching, information, standards, etc.), not forget your established mission,
4/ after-action review (heuristic evaluation – e.g. some independent expert can do it, etc.), make some corrective actions and feed-back and prepare that WPs which is good for serial production.

The problem on how to produce revolving drum for a washing machine using ABT and iQSim welding simulator could be handed, at least, in three phases:

**ABT/iQSim welding simulator - Phase 1.:**

1/a - Choose the parent material according CR ISO 15608, define the thickness (max. 0,8 mm) necessary and prepare pWPS, using your iQSim welding simulator

1/b - Explain and verify your decision on sort of parent material and all parameters in pWPS and please demonstrate it using your iQSim-welding simulator.

**ABT/iQSim welding simulator - Phase 2.:**

2/a - Prepare a testing, controlling plan and explain what does it mean conformity and how conformity assessment and testing are interdependent? Argue why conformity assessment is necessary? Which rules/standards could used?

2/b - Choose standards for this activity. If you have problem then please contact your instructor he can explain ISO 15614, and ISO 15614-1, if you don’t remember.

2/c - The test pieces according to ISO 15614-1 shall be drawn and after welding prepared (produced) for testing – a shorten testing is acceptable if agreed by your instructor.

**ABT/iQSim welding simulator - Phase 3.:**

3/a - Material NDT and other destructive testing should be done. The test results and the iQSim welding simulator services provided data and information should be documented compared with test results.

3/b - Assessment and evaluation should be made. After your corrective actions established using the new – improved - welding parameters and your iQSim- welding simulator you should verify if they are correct. A conformity certificate – as document - should be done as well.

3/c - Please determine the costs of the whole welding related operation to produce a long life cycle revolving drum using your iQSim welding simulator.

3/d - Conclusion using both data of iQSim welding simulator and test results should be made alone and later your results and recommendations should be consulted by your instructor (or teacher) and/or presented to your class.
**Students create their own WPS**

Quality of product is specified and the students have to figure out which parameters to use (NO + LT)

By using the simulator both for the joint configuration and also for the welding process data, the teacher and the student can develop a pWPS (Preliminary Welding Procedure Specification) and document it. The next task can then be to weld a test piece. Then compare the real results with the preliminary obtained data. By carrying out different simulations then multiple pWPS can be defined and at a later date being welded in the shop in order to verify the data.

Through the interaction between the use of the simulator, which is the theory, and practical welding in the shop, the students will be able to manipulate the technical parameters. Through this exercise they will also experience, the influence of the different parameters both from a theoretical point of view as well from a practical point of view through the welding experience in the shop.

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**Example of tasks given to students—Task 1**

![Diagram of welding process]

Two plates, each 25 mm are going to be welded in position PF.

You have the following data available:

- Material quality: S355K2G3
- Electrode data: OK 48,08 and diameter 3,25mm.

Task: Find the preheat temperature and create a pWPS
Example of tasks given to students—Task 2

Material quality: S355K2G3

Material analyzes according the material certificate: 0,22% C, 0,22% Si, 1,70% Mn, 0,024% P, 0,009% S, 0,06% Cu, 0,02% Ni, 0,09% Cr, 0,01% Mo og 0,023% V.

Two pWPS´s shall be developed for the above fillet weld.

The first pWPS shall be created with a 4mm OK Femax 38,48 electrode. Amperage should be within the following region:160 - 210 A, and voltage between 26 - 28 V.

The second pWPS shall be created with 1,6 mm FCAW OK Tubrod 15,17. Welding parameters: Amperage 200 - 300 A, voltage 24 - 28 V. Wire feed speed: 6,0 - 10,0 m/min and diameter for the gaz nozzle is 15 mm.

Tasks:

a) Create two pWPS. Which method will you prefer and why?

Through tasks like this the students may the play with the variables and create a plan for the most efficient pWPS. Then they may discuss within the group using the Smartboard and the simulator extensively for evaluating the theoretical alternatives.
iQSim Development of Innovation

### iQSim simulator services used in combination with other learning technologies

To use the SRS in connection with the simulator tool gives advantages in the learning process. If we start with the form of learning the students are using computers and the Internet for the tool and they just add the SRS web site. It means that no extra time is needed to access the SRS, while the ability to use SRS is ever present. Also the possibility to use pre-planned questions mixed with spontaneous asked question gives a flexibility to shift focus from the technology to pedagogy.

In our experience we used spontaneous asked question more and more during the teaching and the purpose was to check if all the students was ready to go to the new level.

The general reflexion from teachers:

- It is simple to give feedback because of the approach - not ashamed of given the wrong answer
- Easier to work with motivation and reflection, the students can reflect on their own learning.
- Simple - the technology works
- Easier when the computers are already running

To think about before using:

- Projector in the classroom
- There is access to the internet via computer or telephone
- It is an advantage if the computers are already part of the teaching

Teacher preparation:

- A database of good questions, about 100 questions that gradually can be improved
- Provides a basis for teacher self-reflection, what I say and why for planning the next lesson
- In forehand, learn to manage technology

What is happening during the teaching period:

- Sharpens learning, motivation and reflection
- Becomes an integrated part of teaching.
- Provides a feeling that "I learned it."
- Becomes clearer - could - could not – explanation
- Direct feedback - formative assessment
- Commitment - motivation - the sensors are on even outside the classroom.

Long-term effects:

- Teaching will be more reflective – teachers will be looking at their own teaching.
- The students will get higher grades due to reflective teaching
- More confident students – they can repeatedly see what they learnt
7. Discussion and conclusion

The simulator services contribute to the modernization of the VET system by promoting virtual simulator tools that address the technological needs in industrial training. Furthermore, it involves development of new training methodologies in combination with pedagogical sound implementation of predictive virtual welding simulators. The new training methods provide a new European learning environment and new training paths to VET schools, instructors and mechanical industry.

The simulator tools introduce a new industrial evaluation process both in front of the training and after the practical laboratory work has been completed, by comparing the proposed data with the measured real life results. The simulation and modelling part is based on simplified mathematical formulas and algorithms related to fusion welding by using operational characteristics, which correspond to good practice (Nippon Steel). European Community supports the work presented in this paper as a development of innovation project under the Leonardo da Vinci program.

The simulator is ideal as a focal point for discussions and reflections in groups, as well as for the interactive interplay during discussions between the teacher and the students. Such interplay may also include the presentation of the mathematics itself, whereby the students may better understand the consequences of physical principles and the mathematical calculations.

A number of use cases and tasks have been developed based on practical industrial production in order to use relevant problem-based training scenarios. They can be used stand-alone in such a way that the teacher demonstrate the tasks and effects on a Smartboard, by demonstrating what is done. Or he/she asks the students about what to do in the next steps. Through the communication with and between the students they have to find a solution and agree upon the physical parameters to be used. Alternatively, the cases may also be presented to group of students, or as individual tasks for each student, whereby the students can reflect around the problem and try to figure out a possible solution.

The use of the simulator is essential in understanding a specific user case. It is mandatory to let the students reflect around the possible causes for a problem, and then suggest a possible explanation or solution to the problem. The possible explanation may also be found in the practical exercise in the shop when the agreed preliminary Welding Procedure Specifications (pWPS) are welded and later tested.

A central part of a pWPS is to figure out the number of weld layers and the heat input for each pass. The correct heat input ensures a thermal balance in the weld so that the heat affected zone and the hardness is within acceptable limits. By altering the variables the students can then select the parameters that will prove most effective in practical welding and later test these parameters in the welding shop.
By using the simulator both for the joint configuration, V-bevel, and also for the welding process data, the teacher and the student can develop a pWPS and document it. The next task can then be to weld a test piece and the compare the real results with the preliminary obtained data. By carrying out different simulations then multiple pWPS can be defined and later welded in the shop.

Through the interaction between the use of the simulator and practical welding, the students may observe and experience the influence of the different welding or material parameters both from a theoretical point of view as well from a practical point of view.

The student may the play with the variables and create a plan for the most efficient pWPS and discuss that within the group at the Smartbord and later prove the results in the shop.

The pedagogical framework may utilize Activity Based Training solutions (Stav 2008). The knowledge construction follows a logic sequence that always starts from the simple to the complex (Alfonso 2004). The teaching scenarios and consequences for new training methods combine the perceptive and cognitive aspects in a simulation perspective (Bodic 2004, Arias-Joran 2005).

The interplay between theoretical reflections and discussions and the verification of the discussions through practical welding in the shop let the students learn the interrelations between essential process parameters and their importance for the practical work.

The combination of technical simulations with economical analyses has been an important factor during the education process. Instead of only focusing on the technical topics, the students have to discuss the economical consequences of their decisions when developing a pWPS.

One of the course providers that have been using the iQSim simulator formulated the following: “We have never seen welding students in front of Smartboard, eagerly discussing technical problems in welding”

The iQSim simulator services provide flexible online tools that may stimulate reflective cognition processes. The students must first carry out a simulation, before they verify the proposed simulation results in later practical test. By applying such an approach the student is able to simulate the effects of selecting different welding process related parameters, and then carry out the practical welding with the same parameters. After welding test pieces can be created and both non-destructive testing, and destructive examination can take place in order to verify the results. This may be done with the technical parameters, but also the economical aspect of the welding process may be simulated both theoretically and practically through shop welding for verification purposes.
The modern society is extensively depending on welded products. Unfortunately, no high quality, easy accessible, integrated and multipurpose online welding simulator tools are available on the market in Europe to help Vocational Education and Training (VET) schools, instructors and welders to make up user friendly process training where the students may reflect and discuss practical tasks as shown in the tasks here. Furthermore, it involves development of new training methodologies in combination with pedagogical sound implementation the welding simulator. The new training methods provide a new European learning environment and new training paths to VET schools, instructors and mechanical industry. The proposed new learning environments and simulator tools will have the potential to help transforming education and skills upgrading processes in Europe according to the Lisbon strategy. They improve the quality and effectiveness of education and training systems in Europe. It is of major importance to support the development of innovative ICT-based content and services by providing a new type of training and learning environment where the simulator tools hide advanced mathematical calculations, which today is a barrier for further education and training for a number of students.

The simulator tools introduce a new industrial evaluation process both in front of the training and after the practical laboratory work has been completed, by comparing the proposed data with the measured real life results. Thus iQSim provides a new learning environment for improved transfer of theoretical knowledge and competence within welding sciences by offering welders and their instructors a new training environment. From the industrial fabrication process point of view, it’s very important to improve learning environments that reduce failures related to cracking due to increased hardness in the material, which usually must be followed up by expensive repair procedures.
8. References
Alonso F., Lopez G., Manrique D., and Soriano J. (2004), Instructional methodology for e-learning content development, proceedings from the IADIS International Conference CELDA 2004
E. Engh: Education of welders in Norway, Sveiseaktuelt. 2004
E. Engh: Interview with teachers at welding conference in Stjørdal, Norway, 2008
“Getting started with ODL” (ISBN 90-441-1898-6).
Erik Engh: Teaching English with technology – special issue on LAMS and learning design volume 2, 9 (3), 53-63. 53. Design of learning sequences for vet (vocational education and training) community using LAMS. Experience from Leonardo da Vinci projects
Bob Harrison: What is Problem-Based Learning? Sierra Training Associates (www.sierra-training.com)
The iQSim project, 2008-2010, online at http://histproject.no/node/50
M. Kilman, Hammare Svetsteknik, Presentation, IW Meeting, Oslo, 2004
Margaret Kiley, Gerry Mullins, Ray Peterson and Tim Rogers: Leap into...Problem-based learning (PBL), The University of Adelaide – Australia
Jamie R. Kirkley, Sonny E. Kirkley, Ph.D., Thomas E. Myers, Nathan Lindsay, Michael J. Singer, Ph.D. Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC) 2003 Problem-Based Embedded Training: An Instructional Methodology for Embedded Training Using Mixed and Virtual Reality Technologies Information in Place, Inc. (IIPI) U. S. Army Research Institute for the Behavioral & Social Sciences, Simulator Systems Research Unit Bloomington, IN Orlando, FL {Jamie, Sonny, Tom}@informationinplace.com, nlindsay@indiana.edu, Mike_Singer@peostri.army.mil
J. B. Stav, "Experiences with activity based training methods in vocational education", proceedings from the IASTED international Conference Computers and Advanced Technologies in Education, Crete, Grece, September 29–October 1, 2008