Report of the Consultant's Meeting on the development of an E-learning system for radiation technologies applications in industry

27-31 January 2014
Vienna, Austria

International Atomic Energy Agency

Contents

1. INTRODUCTION

The Consultant's Meeting (CM) on the development of an e-learning system for radiation technologies applications in industry (radiotracers and nucleonic measurement systems) convened at IAEA headquarter in Vienna, Austria, from 27 to 31 January 2014. The meeting was held with 6 experts from Germany, Korea, France, Croatia, Indonesia and Albania to discuss and evaluate issues related to the development of an e-learning system for radiation technologies applications in industry and about the mechanisms for e-learning implementation. The list of participants is attached as Appendix I.

The foremost objective of the consultant's meeting is to prepare a technical document which will provide practical information and guidelines for the development of an e-learning system for radiotracers and sealed source applications in industry. The preparation of a technical report on status and strategy for the development of the e-learning system was the main output of this CM.

Nuclear techniques, as tracers and sealed sources applications, have been widely used in various industries to optimize and monitor processes, improve product quality, save energy and materials and reduce environmental impact. Their technical, economic and environmental benefits have been well demonstrated and recognized in many industrial sectors. The major radiotracer and sealed source techniques have been transferred to many developing MS through IAEA TC projects. The usefulness of nuclear techniques in evaluation or trouble shooting industrial processes has been proved beyond doubt. There are many instances, where nuclear techniques based on either open or sealed sources have been used on laboratory and industrial scales to provide solutions to problems which otherwise would have been insoluble.

It was not reported but there must be numerous requests for tracer tests or sealed sources applications which cannot be performed or which provided imperfect results because the application group was not able to obtain the best fitted source, or was not able to obtain the permission for the use of radioisotopes for field experiments in time,

The radiotracer technology developed at earlier stages is now being applied by developed countries as routine procedures and their results are not often reported in literature. Many developing countries have also gathered a considerable technical knowledge and experience to apply this useful technology to the benefit of local industry. International Atomic Energy Agency has played an important and leading role in transfer of technical knowledge and the technology itself from developed to developing member states through its Technical Cooperation Programme.

There are lack of technical knowledge and experience, limitations due to lack of equipment, non-availability of radioisotopes, strict regulations not technically related with real radiological safety impact, etc. The society for radiotracer and sealed source is requested to solve the problems through various cooperative activities. Training is provided by IAEA through fellowships, expert missions for group training and regional training courses. But it appears clearly that a complementary training system is necessary to develop the activities and to ensure its sustainability among Member States.

Previous consultant's meeting on the establishment of a training and certification system for radiotracers and nucleonic control systems (NCS) applications, which was held in Vienna, Austria, from 2 to 6 December 2013 developed the scheme that gives general structure of quality management system (QMS) which is used for non-destructive test (NDT) training and qualification of personnel and would be used for radiotracers and sealed sources applications. The scheme is presented on Figure 1. The concept was followed at this consultant's meeting in developing e-learning system.

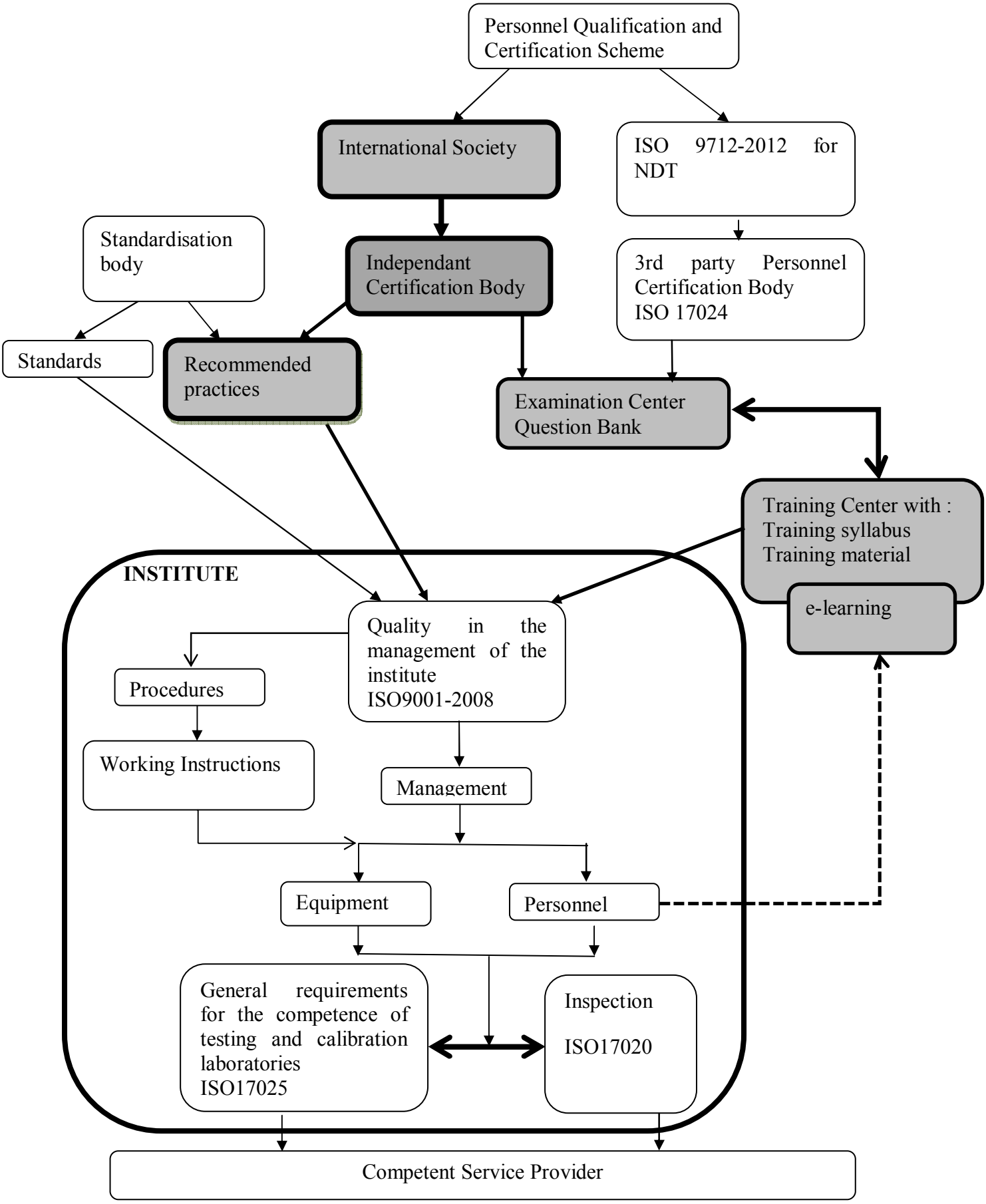


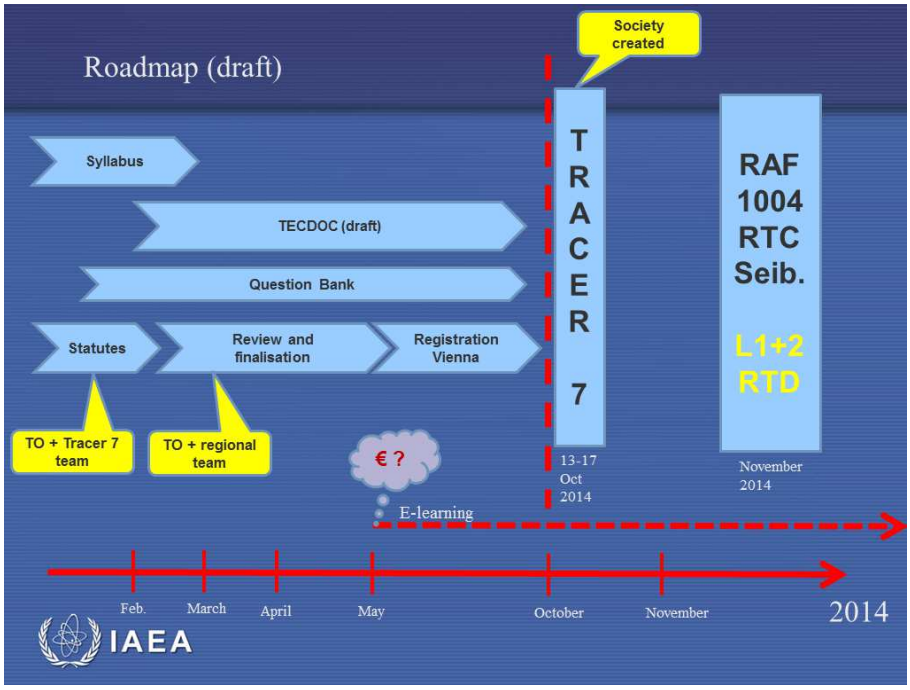
Figure 1. General structure scheme

2. PARTICIPANT'S PRESENTATIONS

During first day all participants delivered presentations about their specific experience and views on e-learning tools that are used for different training purposes and objectives. The presentations were a good basis for a number of issues, questions and suggestions that have to be discussed during the CM. The main issues are:

- Teaching approaches for the domain of radiotracer and sealed source applications.
- Targeted audiences.
- Which concept is appropriate ?
  - e-learning (on-line/off-line), b-learning (blended) or m-learning (mobile)
- E-learning tools to be utilized
  - quizzes, tests, dictionary, videos, audio recordings, animations, interactive content, grading system, etc.
- To scenarize the diversity of activities into a training scheme (script…).
- Which part of the syllabus to transfer into e-learning ?
- Follow-up of learner and his/her competences.
- Pedagogical and teaching methodology issues.
- Language issues.
- Live recordings of lectures and/or audio contents and post production.
- Intellectual property issues.
- Investigate platforms/solution: LMS(Learning Management System), CMS(Content Management System).
- Compliance with SCORM (Sharable Content Object Reference Model)/AICC (Aviation Industry Computer_based training Committee) standards
- Train the trainer/teacher to LMS?
- Promote webinar meetings or MOOCs(Massive Open Online Courses), xMOOCs, cMOOCs, SPOC(Small Private Open Course).

The scheme below presents the position of the e-learning within the context of IAEA tracer project activities and on the drafted timeline [provided by Mr P. Brisset].



Due to the anticipating constrain on the fund for the production of e-learning material, the meeting recommended to produce the e-learning materials for a few priority techniques. Residence Time Distribution (RTD) technique using radiotracers and column scanning technique using sealed sources were selected as the priority areas.

Through discussions the following scheme (Figure 2) has been developed including the most important issues that logically lead to the meaningful design of e-learning system.

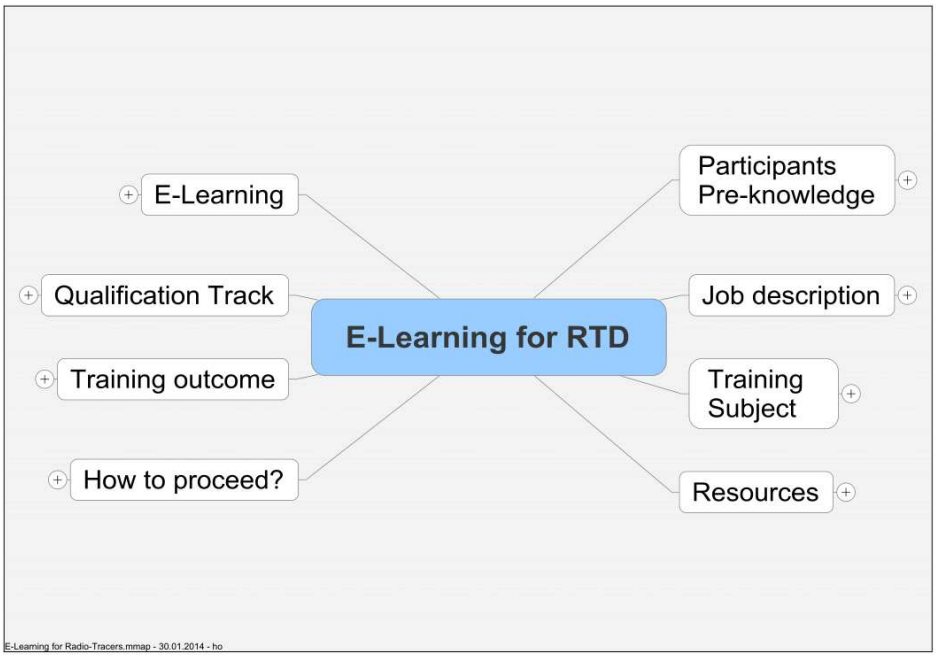


Figure 2. Main issues relevant for development of e-learning for RTD

Each of the eight issues is described in the following chapters. The starting point for designing process of e-learning system should be the analysis of the job descriptions and requirements during application of radiation technologies in industry.

3. JOB DESCRIPTION

It was recommended to establish a quality management system (QMS) for training nondestructive diagnostics evaluation (NDE) methods and qualification of personnel by the Consultant's Meeting on the "Establishment of a training and certification system for radiotracers and NCS applications", which was held in Vienna, Austria, 02-06 December 2013. The training and certification scheme is shown in Figure 1.

The meeting agreed to specify three "levels" of qualification, usually designated as Level 1, Level 2 and Level 3. for the training and certification of the workers for nondestructive diagnostics evaluation methods the roles and responsibilities of personnel in each level are defined as follows.

Level 1

An individual certified to Level 1 has demonstrated competence to carry out NDE, such as set up equipment, perform the tests, record and report the results of the tests, and clean the site, under the supervision of Level 2 or Level 3 personnel. Within the scope of the competence defined in the certificate, Level 1 personnel may be authorized by the employer to perform the tasks described in Figure 3. Level 1 certified personnel shall neither be responsible for the choice of test method or technique to be used, nor for the interpretation of test results.

Level 2

An individual certified to Level 2 has demonstrated competence to perform NDE according to NDE procedures. Within the scope of the competence defined in the certificate, Level 2 personnel may authorized by the employer to analyze the task, organise standard procedure, analyze data, prepare report, and control activity of level 1. Detailed tasks of Level 2 are described in Figure 3.

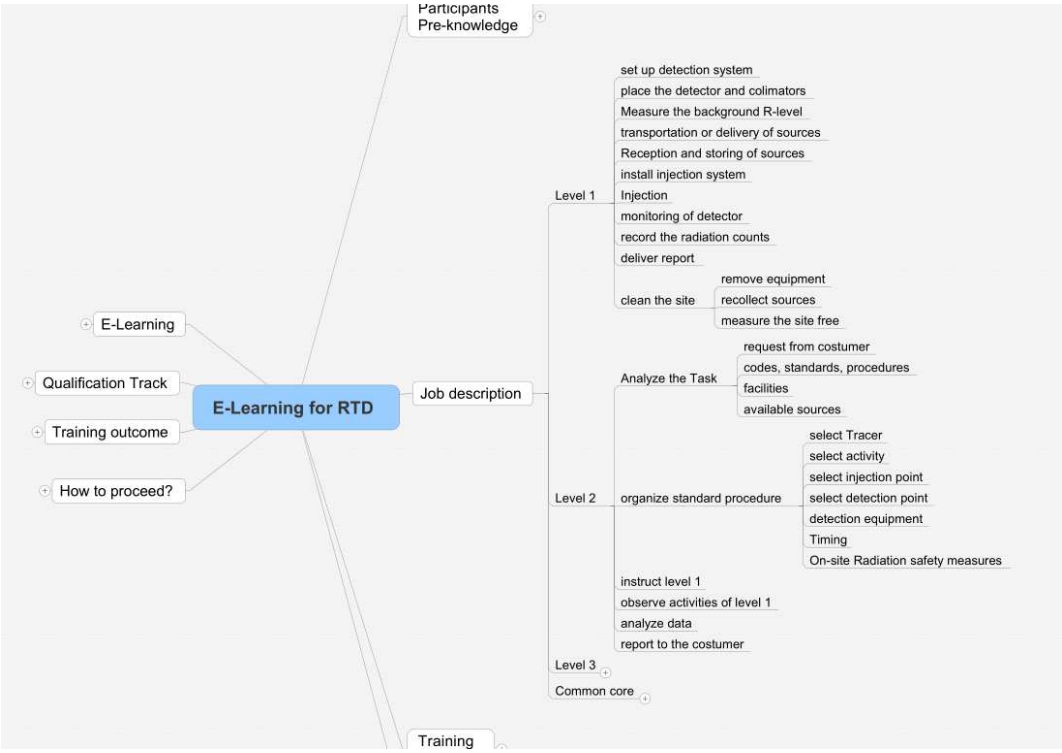


Figure 3. Job descriptions for Level 1 and 2

Level 3

An individual certified Level 3 has demonstrated competence to perform and direct NDE operations including the competence to evaluate and interpret results, sufficient practical knowledge of applicable, materials, process, and product technology to select NDE methods and establish NDE techniques, and a general familiarity with other NDE methods. Within the scope of the competence defined in the certificate, Level 3 personnel may be authorized to perform the tasks described in Figure 4.

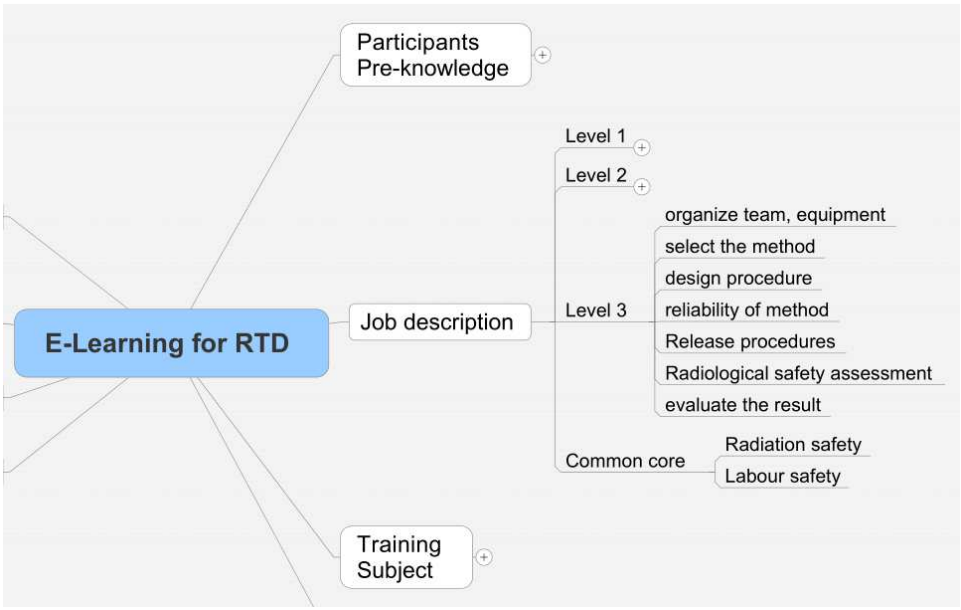


Figure 4. Job descriptions for Level 3

4. PARTICIPANTS PRE-KNOWLEDGE

Having in mind qualification track, training subjects and process of the e-learning, the requirements for access of the candidates to a certain Level of training course are analyzed to satisfy minimum prerequisites for successful achievement of e-learning objectives. The prerequisites were recognized as required pre-knowledge and previous practical experience in industrial applications of the certain method/technique of the radiation technologies. As the targeted group of the trainees is worldwide, the International Standard Classification of Education (ISCED) standard for levels of education should be appropriate. According to the ISCED 2011 the pre-knowledge should be as presented in Table 1 and Figure 5. Proposals for previous practical experience in industrial application are also given in the Table.

Table 1. Pre-knowledge required for Levels 1, 2 and 3 according to ISCED 2011

RTD Levels	ISCED Level	ISCED Level Description	Required practical experience
Level 1	ISCED Level 3 Upper secondary education	Second/final stage of secondary education preparing for tertiary education and/or providing skills relevant to employment. Usually with an increased range of subject options and streams	6 months
Level 2	ISCED Level 5 Short-cycle tertiary education	Short first tertiary programmes that are typically practically-based, occupationally-specific and prepare for labour market entry. These programmes may also provide a pathway to other tertiary programmes.	1 year
Level 3	ISCED Level 6 Bachelor or equivalent	Programmes designed to provide intermediate academic and/or professional knowledge, skills and competencies leading to a first tertiary degree or equivalent qualification.	see definition (credit system)

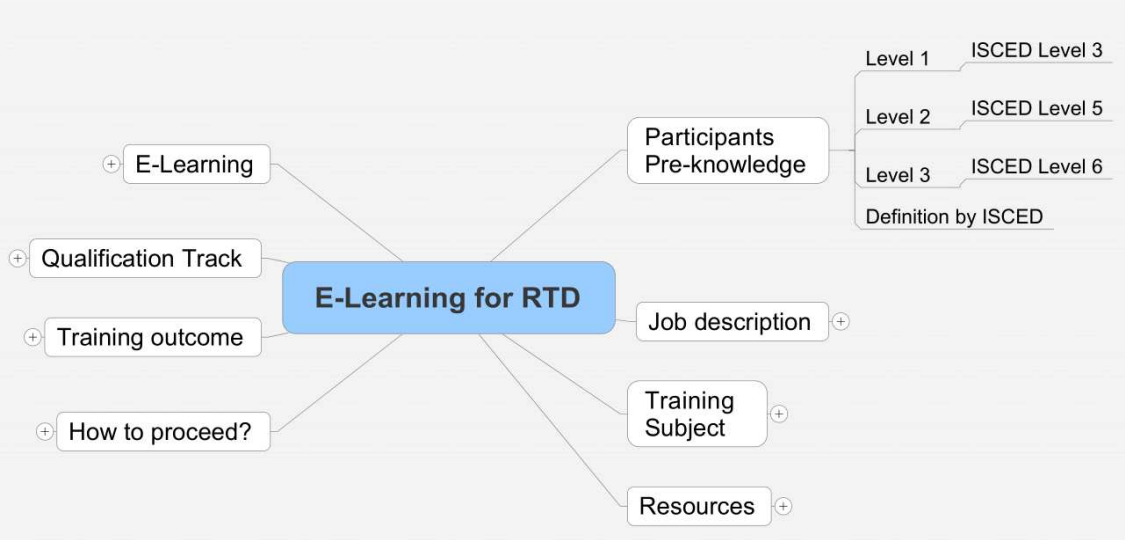


Figure 5. Required ISCED Levels of pre-knowledge

5. TRAINING SUBJECT

Training frame with descriptions of training subjects to be included in e-learning course is given in the Appendix II. It consists of nine sections (additional resources to be added if needed) that have to cover knowledge and skills to be trained as it is presented on Figures 6-8 for each of 3 levels.

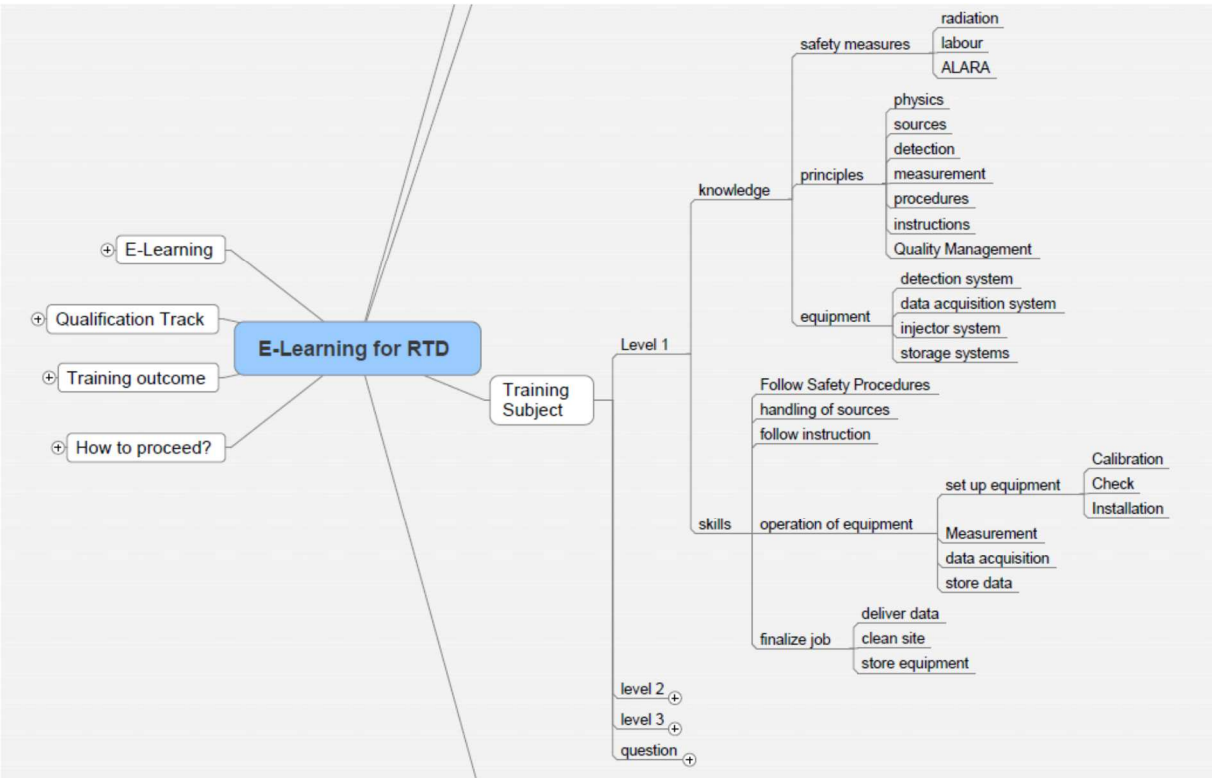


Figure 6. Training subjects for RTD Level 1.

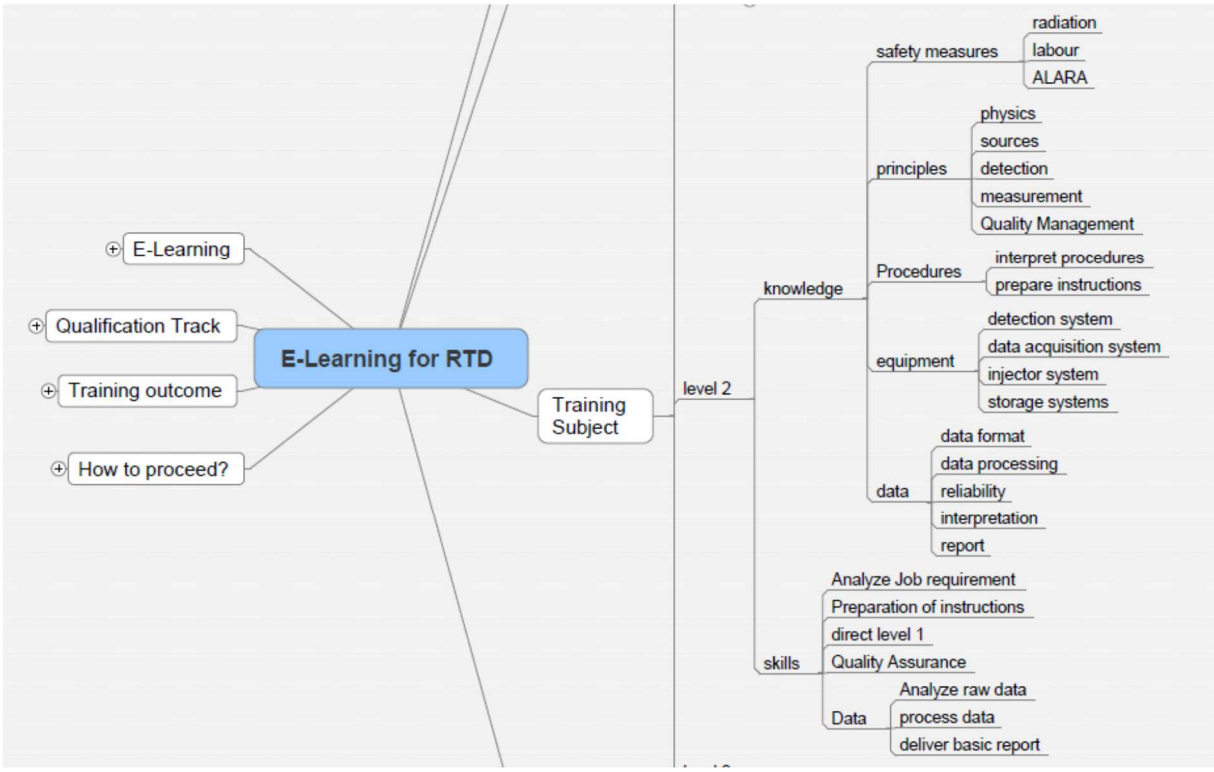


Figure 7. Training subjects for RTD Level 2.

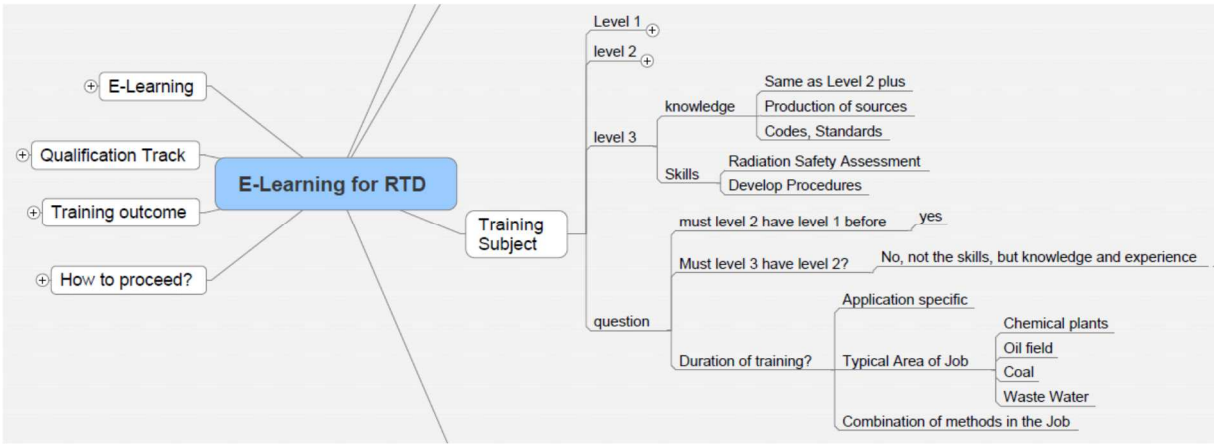


Figure 8. Training subjects for RTD Level 3.

6. RESOURCES

A number of resources in the field of radiation technologies applications in industry (radiotracers and nucleonic measurement systems) already exist in portfolio of IAEA. These have been developed through the past IAEA activities for different purposes. Anyhow, these resources present a good basis for development of the e-learning materials, and some of them, especially text, could be used to develop lessons of the e-learning course.

Some of the existing resources like animations, videos, photos or graphs could be used on conceptual basis but some adjustments to the new media standards and/or formats should be expected. This is important also from the pedagogical and teaching methodology aspect of the e-learning course.

The list of existing and available IAEA publications on radiotracer & sealed source technology has been presented [Mr Jin]:

IAEA Technical Report Series

- Guidebook on Radioisotope Tracers in Industry (TRS-316, 1990)
- Guidebook on radiotracer applications in industrial processing and oil and geothermal reservoirs (TRS-423, 2004)

IAEA Radiation Technology Series

- Application of Radiotracer Techniques for Interwell Study: A Guidebook (RTS-3, 2012)
- Radiation Generators for Industrial Applications (RTS-5, 2013)

IAEA-TECDOC

- Emerging new applications of nucleonic control systems in industry (TECDOC-1142, 2000)
- Radiotracer technology as applied to industry (TECDOC-1262, 2001)
- Integration of tracing with computational fluid dynamics for industrial process investigation (TECDOC-1412, 2004)
- Technical Data on Nucleonic Gauges (TECDOC-1459, 2005)
- Industrial process gamma tomography (TECDOC-1589, 2008)

IAEA Training Course Series

- Radiotracers Residence Time Distribution Method for industrial and Environmental Applications (TCS-31, 2008)
- Leak Detection in Heat Exchangers and Underground Pipelines Using Radiotracers (TCS-38, 2009)
- Radiotracer Techniques for Wastewater Management Plants (TCS-49, 2011)

IAEA Brochure

- Radioisotope applications for troubleshooting and optimizing industrial processes (2002)
- Tracer applications in oil field investigations (2003)
- Radiotracer applications for leak detection (2004)

Software

- Residence Time Distribution Analysis: DTS Pro, K-RTD, FEMINA
- Thin Layer Activation: TLA
- Interwell Data Analysis: ANDURIL, PORO

- Monte Carlo N-Particle Transport Code (MCNP) : Janu, Macalu, Ecrin
- Data Acquisition Systems: DOZEN

Other Technical Documents

- Protocols and Guidelines
- (ISO Standards)
- Training Materials for RTCs
- Promotional Materials
- Expert's Technical Reports
- Report of Task Force Meeting on Design and formulation of ICT-based training material on radiotracer and sealed source applications in industry, RAF/8/040 project, August 2006

Some of the resources mentioned above are not directly related to RTD technique, but they will be used for the development of e-learning materials for other technical fields. Several materials most useful for RTD e-learning material were selected in Figure 9:

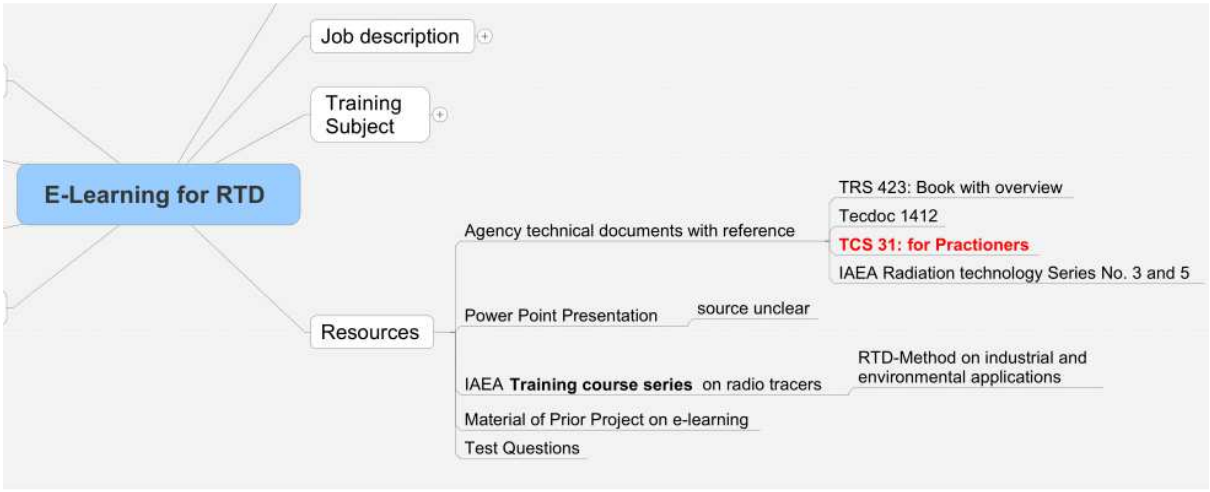


Figure 9. Types of resources to be taken into account for e-learning development for RTD

7. E-LEARNING

At first, it is important to consider what component of competence targeted brings the distance learning system. From the three components, "knowledge, skills and attitude", and taking into account the target job profile of trainees, the e-learning solution will focus mainly on knowledge which will be acquired by personnel implementing radiotracers.

Distance learning will be based on a Learning Management System (LMS), whose main features are defined in terms of desired learning outcomes (final evaluation, results of quizzes ...). With e-learning, freedom of action is very large but is limited by the available time, financial resources and needs of learners. Several methods for e-learning can be considered. They depend on the pedagogical strategy chosen.

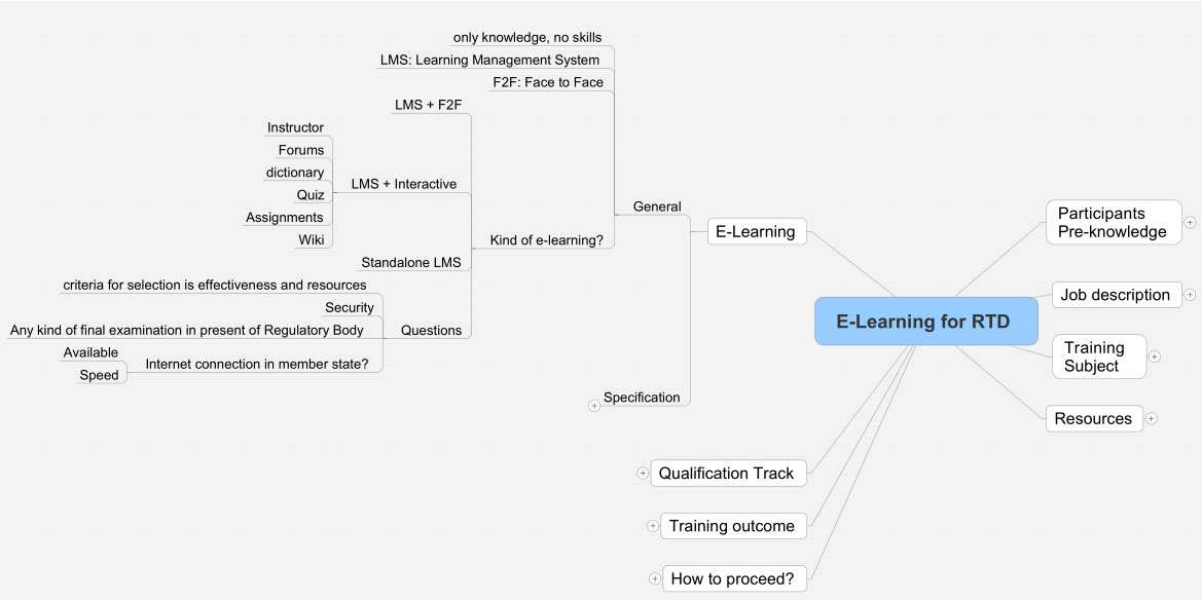


Figure 10. General overview of e-learning issues

The use of e -learning resource can be synchronous or asynchronous or a combination of both. The learner can acquire knowledge using e-learning or b-learning (blended learning) by combining e-learning with face to face learning. Depending on the IT device used, the term of m-learning appears few years ago when learner uses for example a mobile device such as Smartphone or tablet PC. It is a one of the main feature of e-learning that allows to train “everywhere”.

The degree of interactivity offered by the IT solution may vary. This will depend on the nature of the proposed activities to the learner: reading text, viewing explanatory animations, answer quizzes and others. Finally, the degree of cooperation, ranging from "no collaboration at all" (the learner interacts only with the computer) to "full cooperation" where a network of learners allows them to use a forum and thus participate in a process of co-construction.

Different kind of learning could be considered to train practitioners.

- e-learning (mostly text)
- e-learning + interactive content (Richmedia resource)
- stand-alone system (DVD, USB…)

For all the type of distance learning, a description of features needed has to be described (tutor/instructor, glossary, dictionary, quiz, wiki, assignment, forum…). During the process of developing such e-learning, issues related to the implementation arise, such as:

- Criteria and indicators for the selection and effectiveness of a learning resource
- Computer security
- Mode of examination by/with regulatory
- Speed transmission of data via internet in MS.

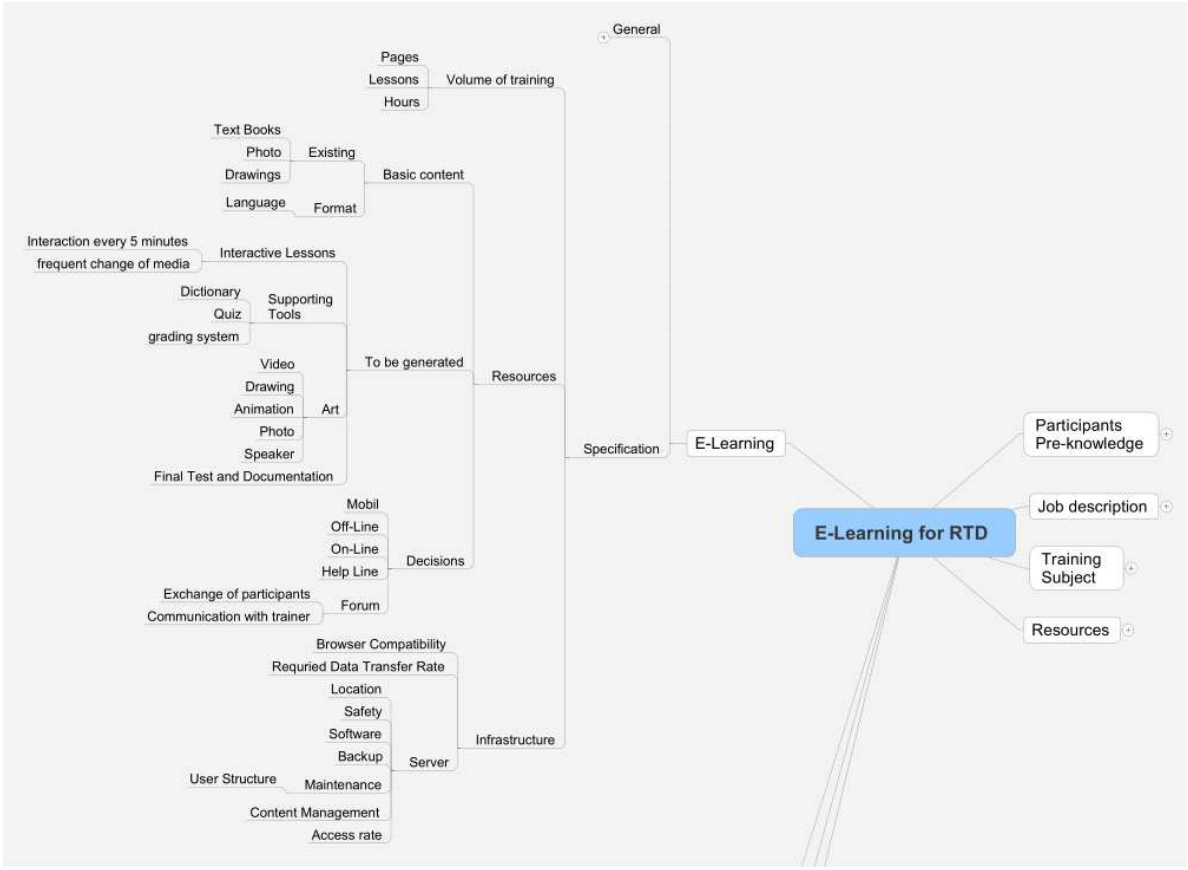


Figure 11. Overview of e-learning specification

7.1 Solicitation for e-learning

The design and delivery of an e-learning system should be the work of a professional and experienced company. It seems to be impossible to build up such a solution within expert meetings. The following key elements of the solicitation for an e-learning system have been identified. Inside the key element the minimum requirements for a statement of the bidder/provider has been summarized.

1. Objective

Development and delivery of an comprehensive e-learning tool to train people in the field of Radiotracer Applications

- Comprehensive instructional design will be performed by bidder. Course content exists in various forms or nonexistent and must be gathered, organized, and analyzed to create course objectives, outline, preliminary design, and storyboarding.
- Bidder must have the ability to create courses that meet standards (e.g. SCORM, AICC, 508c, etc.), and the courses must avoid the usage of a typical plug-ins.
- The IAEA seeks to identify and use qualified, non-exclusive service providers to develop custom web-based eLearning course(s)

2. Deliverer

The bidder/deliverer should present the following documents and statements:

- Description of the company
- Short history of the company
- Financial revenue of last 3 years
- Organization's custom content e-learning development services and capabilities
- Experience in e-learning
- Sample of work similar in nature
- Three reference customers with address and contact
- Background and experience of key staff

3. Content

The following work is expected to be delivered during the project:

- Define learning objectives, learning strategies, and evaluative measures
- Repurpose existing content to effective and efficient web delivery
- Storyboards
- Prototypes • Usability Testing Recommendations
- Video- encode / compress

4 Teaching Approach

The bidder is responsible for the following tasks:

- Propose Learning Management Software
- Create multimedia files (e.g. HTML, FLASH, etc.)
- Collaborate with instructional designers for most effective online presentation
- Identify technology and infrastructure implications to solution design
- Create custom graphics or identify existing art resources to give course unique identity
- Encode video and audio
- Develop user interfaces
- Pre-deployment quality assurance testing
- Conduct usability testing
- Tests and Surveys
    - pre- and post-training tests
    - tests in each chapter

- question types such as true/false, multiple choice, sentence completion, fill-in-the-blank
- test settings such as question randomization, timed response, multiple question retry, randomized answers
- feedback or explanations, question skipping, grading and scoring

- Potential Users
  - typically access e-learning at their own desks or at a shared workstation

5. Proposed Technology

The bidder needs to define the following minimum requirements for the technology:

- Required versions of web browsers
- Minimum connection speed necessary to run course
- What plug-ins and active x controls are required?
- Session management/cookies requirements to run course
- List of software applications used to developed course
- Graphical images or clip art library used
- Possibilities to modify source codes using standard authoring tools?

6. Legal Frame

In the frame of the bidding some statements have to be made and agreements on rules have to be accepted:

- http://www.iaea.org/About/Business/iaeaforbidders.pdf
- Confidentiality
- Rights
- Copyright of all graphic Material
- Copyright on Text
- Right of usage
- You must agree to give ownership to the IAEA for all materials produced, including source codes at no extra costs.
- Validity of Proposal:

7. Project management process

- Time Frame
- Milestones
- beginning
- End
- Modules
- Testing
- Acceptance process
- Quality assurance
  - Declaration to fulfil SCORM
  - Conduct reviews and overall usability testing

- Create design blueprint and/or storyboard
- Programming/Coding

8. Price

- General
- Overall Price
- Calculation base:
- Time Frame
- Hourly Prices of Expert Gropes (Designer, Programmer, Project Manager)
- Change Requests
- Maintenance
- Licenses

8. TRAINING OUTCOMES

Training should enable the personnel's knowledge and skills to achieve the most competent application of RTD and sealed sources techniques. E-learning should improve the efficiency in training. Training hours at training center can be reduced and focused on specific knowledge and skills related to the method. The training outcomes of each Level were described in Figure 12.

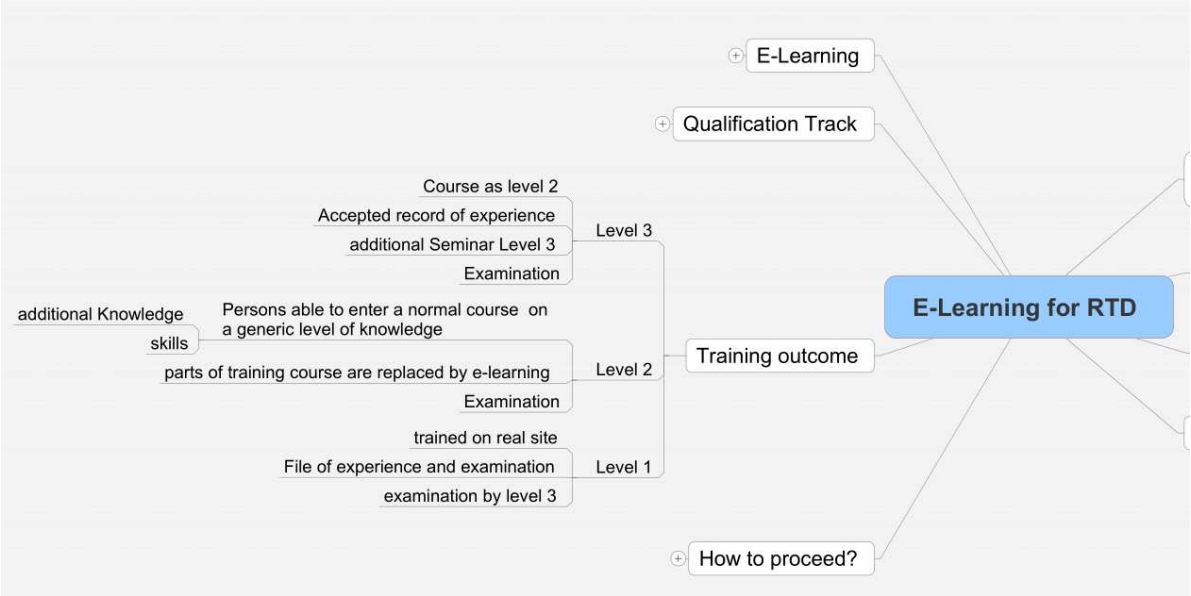


Figure 12. Overview on training outcomes

9. QUALIFICATION TRACK

To get reliable results out of radiotracers experiments it is important to employ well qualified operators and supervisors. Qualification track for radiotracer practitioners is shown in Figure 13.

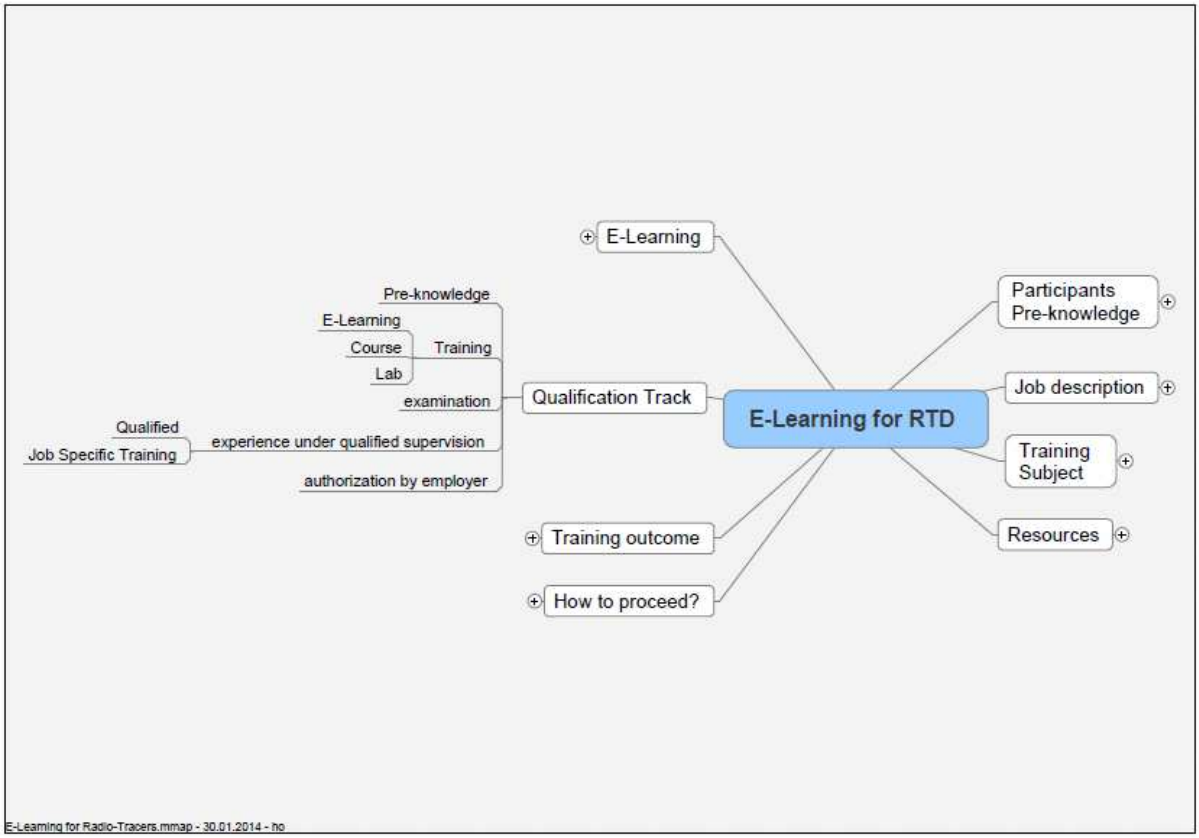


Figure 13. Overview on Qualification Track

The qualification is gained by different sources. Under the responsibility of the employer the personnel has to fulfill the following requirements:

1. Pre-knowledge:
   This is the knowledge from primary or secondary school or study. See also chapter 4. participants pre-knowledge.

2. Training:
   The training delivers in a systematic way basic knowledge and skills for the task. It can be organized as e-learning, training course or laboratory work, but should be delivered by a training organization independent from the employer.

3. Examination:
   At the end of a training, the knowledge and skills of the participant shall be evaluated through a written and practical examination. The examination should be done by an

organization independent from the employer.

4. Experience under qualified supervision
   After the training and before become a responsible operator or supervisor the candidate has to gain sufficient experience in the working field. He has to learn the objective, processes, equipment and environment typical for his/her work place. Qualified supervisor could be an experienced person with a similar or higher level in the method as well as an engineer or scientist in this field.

5. Job specific training
   Before working on its responsibility the candidate has to perform a job specific training. The requirements for this training are defined by the employer.

6. Authorization by employer
   If all requirements are fulfilled the employer is responsible for issuing an authorization to work. All steps of qualifications have to be proofed by a proper documentation. This documentation should be stored by the employer during the employment of the candidate and for additional 5 years after.

10. CONCLUSIONS (HOW TO PROCEED)

- The work in the field of radiotracer applications has been analyzed and the requirements for the personnel have been written down.
- The meeting found it useful and necessary to build up an e-learning system within a complete qualification system.
- The required data and targets have been defined by the group.
- Existing resources of knowledge on radiotracer and sealed source applications were identified and listed.
- The transfer of theses definitions and sources should be done by a specialized company since many technological questions have to be taken in to account.
- The frame for a solicitation in this field was designed.
- The focus should be on the two methods, RTD and column scanning, since they are the mostly used industrial applications and there is the biggest need for qualified personnel.

APPENDIX I. List of participants

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11. APPENDIX II. DESCRIPTION OF TRAINING SUBJECT

TRAINING FRAME	
Section	**Content**
1 Introduction, terminology, responsibilities, qualification system	
2 Physical principles of the method and associated knowledge	RADIATION PHYSICS and DETECTION Radiation and radioisotopes Interaction of gamma radiation with matter Interaction of neutrons with matter Statistics of radiation counting Radiotracer principle Radiotracer injection Radiotracer detection Radiotracer activity calculation
3 Process Engineering, Application and capability of the method	RADIOTRACER GENERATORS FOR INDUSTRIAL APPLICATIONS Radionuclide generators Potentially useful radionuclide generators Chemical preparation of radiotracers from generators RTD FOR CHEMICAL ENGINEERING PROCESS STUDIES Chemical engineering general concepts Types of chemical engineering operations Chemical engineering processes Hydrodynamics of reactors Data analysis and interpretation Major targets of radiotracer applications Petrochemical industry Mineral processing RADIOTRACER APPLICATIONS IN WASTEWATER TREATMENT PLANTS Wastewater treatment technologies Tracer techniques and their utilization in wastewater treatment plants Radiotracer techniques Case studies <u>Methods</u> RADIOTRACER TECHNIQUES FOR FLOW RATE MEASUREMENTS AND LEAK DETECTION Radiotracer methodology for flow rate measurement Radiotracer methods for leak detection in heat exchangers Radiotracer methods for leak detection in underground pipelines RADIOTRACER TECHNIQUES FOR MASS BALANCE AND BATCH MIXING MEASUREMENT Radiotracer dilution analysis Radiotracer techniques for batch mixing measurement RESIDENCE TIME DISTRIBUTION (RTD) method RTD formulation RTD for troubleshooting RTD software for modeling simple flows RTD system analysis LABORATORY WORKS FOR RADIATION DETECTION AND

	RTD MEASUREMENTS AND ANALYSIS Determination of the time required for mixing in batch mixing process and a test for homogeneity of the final product. Detection of dead space and channelling Determination and analysis of residence time distribution in process vessels RTD curves and parameter estimation in combined model systems Flow rate measurement in pipes
4 Equipment	Sources injection systems Radiation detectors for gamma and X-rays Important characteristics and response parameters of NaI (Tl) gamma-ray scintillation detectors and liquid scintillation detectors. Radiation detectors for neutrons Data Acquisition
5 preparation of testing	PLANNING AND EXECUTION OF A RADIOTRACER EXPERIMENT Procedures for conducting field radiotracer applications in industry Preparation of work area and execution of tracer test Monitoring of occupational radiation exposures Regulatory and licensing aspects of radiotracer applications in laboratory PREPARATION OF RADIOTRACERS Important considerations in the selection of a radiotracer Radionuclide production techniques Methods and techniques for labeling Procedures for preparing most commonly used radiotracers Validation of radiotracers Safety Assessment Transportation of Source Handling of sources
6 Performance of Testing	<u>Level 1</u> set up detection system place the detector and collimators Measure the background R-level transportation or delivery of sources Reception and storing of sources install injection system Injection monitoring of detector record the radiation counts deliver report clean the site remove equipment recollect sources measure the site free <u>Level 2</u> Analyze the Task request from costumer codes, standards, procedures facilities available sources

	organize standard procedure select Tracer select activity select injection point select detection point detection equipment Timing On-site Radiation safety measures instruct level 1 observe activities of level 1 analyze data report to the costumer Level 3 organize team, equipment select the method design procedure reliability of method Release procedures Radiological safety assessment evaluate the result
7 Evaluation, Reporting and Assessment	Raw Data Data Treatment Modelling Interpretation Reporting Result Presentation
8 Quality aspects	Documentation Repeatability & Reproducibility Traceability Reliability Procedures
9 Safety Measures	Components of radiation protection Dose and dose rate Principle of radiation protection Radiation protection of staff and public Personnel monitoring equipment Surveillance program Rules for handling of radioactive substances Radiation safety considerations in radiotracer applications Radiation safety considerations in sealed source and nucleonic gauge applications
10 Additional Resources	