THE IAEA E-LEARNING COURSE ON NEUTRON ACTIVATION ANALYSIS

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ABSTRACT

The IAEA released an e-learning course on Neutron Activation Analysis (NAA), the most common technique available in research reactors worldwide, in October 2017. The e-learning course is organized in seven thematic areas, covering comprehensively all aspects of NAA, and including quizzes and other supporting materials. It is directed at young specialists or beginners, but can also be used by experienced practitioners, professors of nuclear sciences and applications & nuclear analytical techniques, and other professionals. In the short time since its release, it already has over 75 enrolled learners from 36 Member States of the IAEA.

1. Introduction

Neutron activation analysis (NAA) is one of the most common activities in the close to 240 nuclear existing research reactors which are operational or in temporary shutdown. 113 research reactors, from sub-critical assemblies to power ratings up to 200 MW, report activity in NAA [1]. Although NAA is a well-established technique, it has been observed that retirement and departure for other reasons of experienced staff often leads to gaps in knowledge of methodological principles and metrological aspects of the technique. This affects both the remaining NAA team as well as transmission of experience to new recruits. The day-to-day expertise in performing NAA is typically obtained by hands-on experimental education and training and knowledge transfer by experienced scientists, a process which may take a relatively long period of time. As such, there is often insufficient or even no overlap time between leaving expertise and newcomers.

Existing books and guidance documents on the concepts and execution of NAA [2-7] may not be sufficient to ensure the timely transfer of knowledge on the practice of NAA. Specifically, the books often lack a dedicated part on errors, their sources and troubleshooting once results are not trusted or unacceptable. Although many practical aspects of conducting NAA have been documented in international scientific literature, especially in the decades of growth (1960s-1980s), this information is scattered, and the knowledge of where to retrieve it often departs together with the departing personnel. Furthermore, access to this literature is not always possible as some institutions, particularly those not integrated in a university setting, do not always have access to the journals.

Since the middle of the 1990s electronic technology (e-learning) has slowly infiltrated and now is present in education at all levels. E-learning encompasses a wide array of deliveries from simple introductions of animations in a teaching class to Massive Open-On-Line Courses (MOOCs) and Modular Object-Oriented Dynamic Learning Environment (MOODLEs). In scientific and engineering areas, e-learning faces the challenge of delivering intricate concepts without the use of a traditional blackboard with a real-life teacher responding to learners' questions. Nevertheless, it is an appropriate method to reach a world-wide diverse community in a fast-moving arena of technological changes in education delivery. The International Atomic Energy Agency (IAEA) has already undertaken large efforts to secure nuclear knowledge management in a wide area of nuclear science and engineering including research reactors [9].

In this paper we report on the development of the IAEA e-learning course on NAA, its status, and plans for further development.

2. Objectives of the e-learning course

The objective of the IAEA e-learning course on NAA is to ensure preservation and transmission of knowledge and experience on the technique. This will be achieved by ensuring that the course will be a 'living book', summarizing the basic concepts of NAA and providing practical information on the implementation of the methodologies, while allowing for easy addition of new developments, updates and improvements of the existing material.

The course also provides information on the practice of sample preparation, how to minimize the risk of errors at different stages of the sample receipt and preparation, irradiation, measurement, data analysis and reporting process. As such, it supports, complements, and to some extent even takes over the educational role of the NAA supervisor. This capacity building tool will contribute to foster experience in NAA on the use of the technique, on the practical implementation, recent developments, sources of error and ways to overcome them in a pragmatic way. Eventually, this e-learning course will contribute to reduce the threshold for using NAA, and thus may provide a path for increased utilization of facilities and research reactors.

The e-learning tool on NAA is directed at young specialists or beginners without sufficient experience of conducting NAA independently, but can also be used by experienced practitioners who want to implement or use another variety of NAA, professional technicians and analysts, users of NAA and other stakeholders who wish to understand the techniques better, professors, undergraduate and graduate students in nuclear sciences and applications and nuclear analytical techniques.

3. Description of the course

The e-learning course for NAA was designed to have a modular structure, allowing for easy revision and expansion. New or better information can be added such as worked-out exercises, animations or movie clips and even new modules. The course is organized in seven areas, covering comprehensively all aspects of NAA: (i) Introduction, history and applications; (ii) Basic nuclear physics; (iii) Calibration; (iv) Instrumentation; (v) Quality; (vi) NAA practice; and (vii) NAA varieties. The tool currently consists of 47 modules, each developed as a lecture with 30 to 60 slides. Most modules have 40 to 50 slides, based on the assumption that the effort for studying each is approximately one hour. The course structure is shown in Figure 1.

For each module, both terminal training objectives and enabling training objectives have been identified. In addition, a short introducing text was written for each module. Lecture notes have been added to the slides wherever relevant. These may eventually be replaced

by narrated voice-over. Self-evaluation has been integrated in the modules based on the multiple choice, short or one-line replies, true/false or corresponding response principle.

The tool is complementary to existing textbooks, but often goes beyond those textbooks, since it comprises information on the practice of NAA that either never has been published or which may require expert knowledge to retrieve. The tool can be expanded with examples of practical cases that occurred in various NAA facilities and which usually are not suitable for documenting in scientific publications. These could eventually be compiled, preserving not just the success stories of the practice but also smart practical approaches and even the (daily) pitfalls.

The grouping of the modules in 7 thematic areas (see Figure 1) allows an individual to choose one, some or all of the thematic areas depending on the duties of the work or research. For instance, a staff member or researcher whose work mainly involves instrumentation may choose only this section to study in great detail, while only cursorily studying the other sections. On the other hand, a person who is only involved in sample preparation or data output may do likewise by only studying the Quality thematic area.

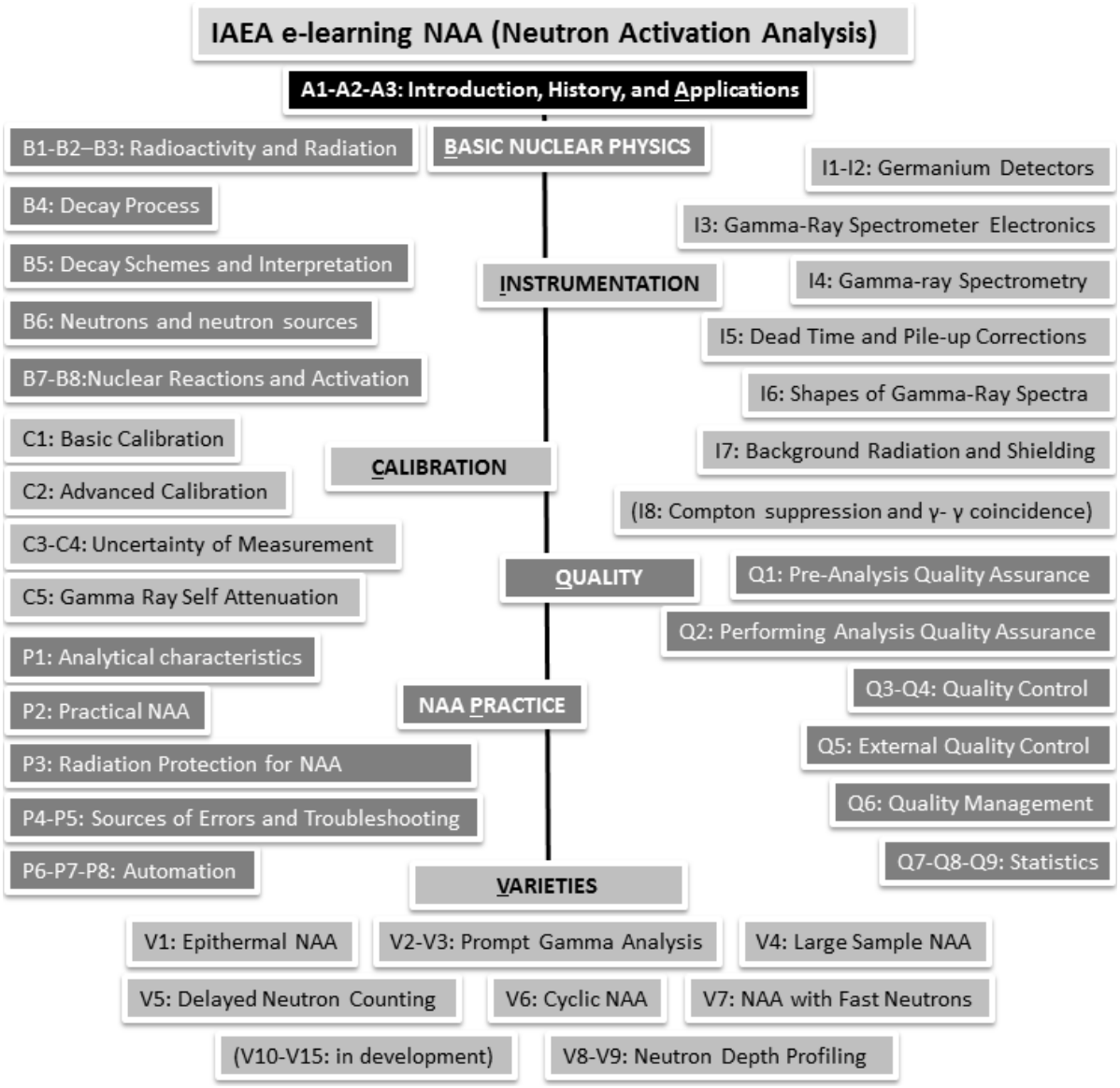

Figure 1. Course syllabus.

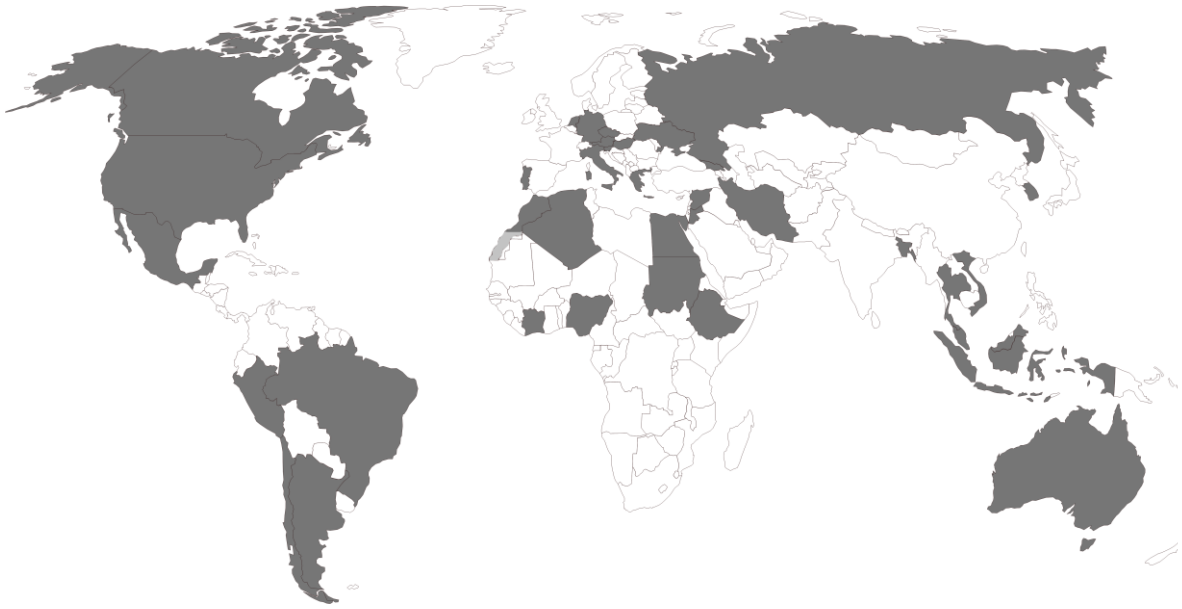

Figure 2. Member States with registered learners on the IAEA e-learning NAA course (as of January 2018).

The tool will act as a 'living book', to be reviewed and updated biannually and, if necessary, extended. It is also expected to serve as an archive, fostering unpublished experimental experiences.

It should be noted that the IAEA e-learning course on NAA will not have teachers as points of contact in the IAEA. The course is designed for self-learning, eventually directed by a teacher or supervisor in the Member State. Learners with different skillsets go online to follow the course, often choosing to take specific modules or thematic areas.

4. Implementation

Most modules were written by two main authors, experts in NAA (PB and SL), with two other authors invited to prepare modules in prompt gamma analysis and neutron depth profiling. The modules and questions have been reviewed by a large group of NAA experts and tested during an IAEA workshop by experienced and new coming practitioners [10]. Following the feedback from this workshop, a final review has been made, with particular attention to the consistency in terminology across all modules and to the self-assessment questions and answers, including whether they can be answered based on the information provided in the course. References to relevant scientific literature have been incorporated.

The e-learning tool has been released in October 2017 in the IAEA Open Learning Management System [11], part of the IAEA Cyber Learning Platform for Network Education and Training (CLP4NET) [12]. The full package, which can be used without internet connection once it is downloaded and installed, is also available for download in the same platform. As of January 2018, 88 registrations were received from 36 Member States, some of them even without operational research reactors (see Figure 2). An indication of the weekly utilization of the e-learning tool can be derived from Figure 3, which shows the number of actions logged in CLP4NET excluding course managers, developers, and IAEA personnel. The utilization peaked following the release of the course, which included announcement in several workshops and conferences.

Roughly 45% of registered users download the full package, but most of those (nearly three quarters) continue to take modules of the course on-line. The download is presumably being used as a fail-safe alternative.

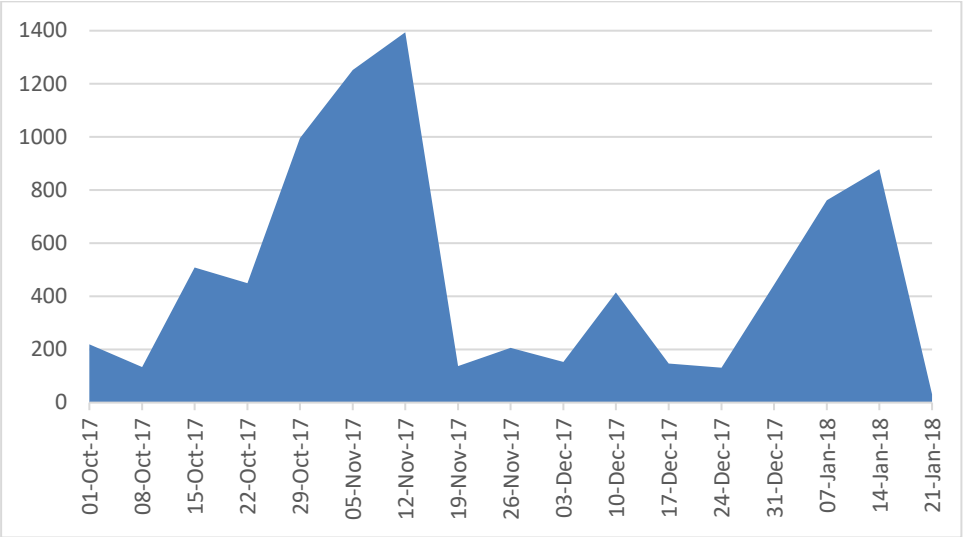

Figure 3. Weekly statistics of utilization of the e-learning course.

The breakdown of course completion by thematic area is shown in Fig. 4. The Introduction area is where most learner activity occurs, mainly concentrated in the very first module. This is presumably where most users start and familiarize themselves with how the course functions, before going on to other modules. In the Basic nuclear physics thematic area, which is the second most popular, all eight modules are more or less equally taken, which indicates interest in the fundamentals of the technique.

The IAEA is also receiving comments from the users, either on small (mainly typographic) mistakes in the slides, or with suggestions for further improvement and expansion of the tool. These will be collected and introduced at periodic reviews of the course. Whenever substantial comments are received, such as mistakes in content, corrections will be made immediately.

A CD-ROM has been made available to serve users that do not have access to a reliable internet connection to use the tool on the IAEA Nucleus website. However, currently there are no plans to update this CD-ROM, which contains the e-learning tool version of September 23, 2017 (equal to the version on-line as of January 2018, except for smaller formatting issues or typographical corrections).

5. Outlook

Expansion of the course is currently under consideration. Modules are considered for development such as (but not limited to) (i) NAA using fast neutrons from accelerators and isotopic neutron sources, (ii) radiochemical neutron activation analysis, (iii) charged particle and photon activation analysis, (iv) in-vivo activation analysis, (v) pitfalls in conducting NAA and lessons learned, (vi) analysis protocols for specific matrices and (vii) applications of NAA, serving as a promotional material for the NAA technique.

The e-learning tool is promoted at IAEA meetings and major scientific conferences relevant to NAA, gamma-ray spectrometry and associated applied sciences (such as measurement of naturally occurring radioactivity).

The continuation of the tool will further depend on the active engagement of the activation analysis community itself by provision of additional teaching material, examples of practical experiences, additional modules with advanced elaboration on specific topics, animations, video clips and exchange of experiences for education and knowledge preservation. The first major review of the e-learning course is scheduled for the third quarter of 2018.

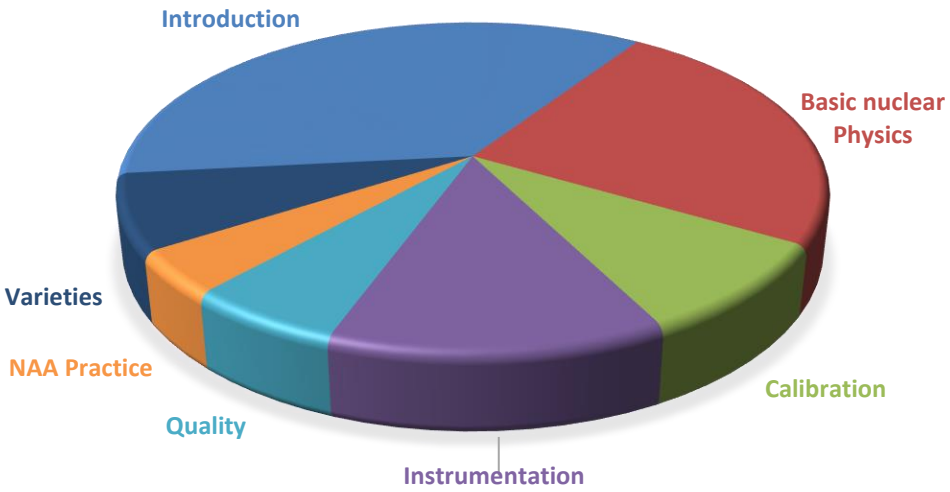

Figure 4. Breakdown of course completion by thematic area.

6. Conclusions

The first IAEA e-learning course dedicated to a research reactor based technique, neutron activation analysis, was launched in October 2017, and made available to the Member States through the IAEA Open Learning Management System. NAA was chosen as it is the most common analytical technique available as research reactors worldwide. The course is organized in seven areas, covering comprehensively all aspects of NAA. It is directed at young specialists or beginners, but it can also be used by experienced practitioners and other stakeholders.

The IAEA e-learning course on NAA is intended to be a living course. Continuous improvement will be done based on the contribution and inputs of the community, and on feedback forms included in the tool. Biannual training workshops are planned, where feedback from NAA practitioners is expected to lead to useful suggestions for improvement. In the short time since its release, the course already has 75 enrolled learners from 36 Member States of the IAEA. The IAEA will continue to promote the course, which will contribute to the sustainability of NAA activities in research reactors.

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