Strengthening scientific literacy on nuclear reactor and its application through Nuclear School

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Abstract. Amid its controversy for application in power generation, nuclear technology is still considered as promising technology for some other application such as in medicine, food, agriculture, water desalination, and other industrial uses. Therefore, knowledge on nuclear technology needs to be preserved and even to be improved. This paper presents an education and outreach activity on nuclear technology, called Nuclear School, as an effort to preserve and improve nuclear science and technology. It is held by the Center for Science and Accelerator Technology (PSTA), as a subsidiary of National Nuclear Energy Agency of Indonesia (BATAN). This activity allows physics and chemistry students, lecturers, and high school teachers in physics and chemistry engage with nuclear reactor and its scientists. By utilizing Kartini Reactor, a 100 kW(th) TRIGA Mark II research reactor type, the participants acquire basic nuclear science as well as reactor physics and operation both in classroom and practice. Safety aspect on radiation and nuclear reactor operation are also provided in order to improve public understanding on nuclear science and technology.

1. Background and motivation

Although application of nuclear technology for power generation in Indonesia has not been implemented yet for a long time, the effort to preserve science of nuclear reactor amidst the society is still encourage. The president of the Republic of Indonesia on the third plenary session of the National Energy Council emphasized that a roadmap should be established for the option of nuclear power development \[1\]. As mentioned in the National Energy Policy (KEN), an action plan from General Planning of Nuclear Energy (RUEN) has mandated to “construction of experimental power reactor and reactor laboratory for nuclear experts to express, interact, and work, as well as provision of support to conduct research in nuclear power field in order to preserve knowledge that is already obtained”\[2\].

Indonesia has 3 (three) nuclear reactor for research purposes. The 2 MW Bandung TRIGA (Training Research Isotope production by General Atomic) Mark-II research reactor, the 100 kW
Kartini TRIGA Mark-II research reactor, and the 30 MW G.A. Siwabessy multipurpose reactor [3][4][5]. Besides for research and material production purposes, the reactors are also utilized for education purposes. The Center for Science and Accelerator Technology, abbreviated to PSTA, is an organization under the National Nuclear Energy Agency of Indonesia (BATAN), which operates Kartini research reactor and hosts an educational and outreach activity called Nuclear School.

Although Nuclear School has been initiated in 2012, it becomes more popular within 2016 and 2017. In 2016, it has been held three (three) times, and until March 2017 it has been carried out twice. Although the Kartini reactor is frequently utilized for educational and training activities, the Nuclear School is unique since the participants were not from specific nuclear-related institutions, such as BATAN, the Nuclear Energy Regulatory Agency of Indonesia (BAPETEN), or education institutions on nuclear science and technology. The participants were university students from science disciplines such as physics and chemistry, including their lecturers, as well as school teachers in physics and chemistry.

The Nuclear School is motivated by the on-going effort on integration between research science and education as well as scientists involvement in education and public outreach [6]. Involvement of scientists and engineers in science education and technology campaign is necessary in order to improve public understanding on science and technology. Some activities are regarded as public outreach such as talks, laboratory visits, family workshops, in-school presentations, and documentary films [7]. Although scientists and engineers are often considered as poor in communication [8] even by their own perception [6], public outreach still could be carried out by utilization of technology model, including computer tools or small machine.

Equipment as a technology advance is practiced in education and public outreach on astronomy science by collaborative effort between United States Air Force Academy (USAFA) and colleges and universities. The USAFA provides telescope, camera, dome, weather station, computer devices while the educational institutions provide building and infrastructure supporting an observatory [9]. Since research facilities also consist of equipment for experimental purposes, laboratory visits or public tours to laboratory are also often scheduled in outreach program [7][10].

This paper presents a successful outreach activity in nuclear science and technology in Indonesia, called Nuclear School, also some lessons learned for future outreach activities are discussed here. In addition, such a documentation on in academic publication regarding education and public outreach on science and technology is needed in Indonesia in order to encourage other scientist and research facilities to organize similar effort. In nuclear science and technology, as Indonesia has several nuclear-related facilities, hopefully those facilities would also conduct outreach activities alike this Nuclear School on a routine basis.

2. Component of the Nuclear School agenda
Agenda elements of 2-day Nuclear School include interactive presentations by scientists and engineers of PSTA in the classrooms, explorations through direct experience with hands-on practices or experiments, and group discussions on practices or experiments results. Figure 1(a) and figure 1(b) represent classroom activity and direct experience learning in the Nuclear School. The material for the Nuclear School is a shorter and simpler version of that for on-job training and coaching for personnel of nuclear-related institutions.

Some elements have certain material module, especially for experiment practices. The each of experiment module is similar with that for on-job training and coaching for personnel of nuclear related institutions. The difference between the Nuclear School and on-job training and coaching is that in the number of element agenda. The Nuclear School has fewer experiment modules than that of on-job training and coaching. Consequently, Nuclear School is only held for 2 (two) days.
In order to complete picture of the nature of 2-day Nuclear School experience, a day-by-day overview of agenda elements is presented in following;

Day 1:
1. Overview of the Nuclear School  
2. Introduction to the facilities in Kartini reactor  
3. Introduction to radiation protection  
4. Visiting Kartini reactor’s facilities and field discussion  
5. Direct experience with reactor start-up and operation  
6. Experiment in power calibration  
7. Experiment in negative coefficient of temperature  
8. Discussions on reactor operation and the experiments

Day 2:
1. Theoretical background on some experiments  
2. Experiment in control rod calibration  
3. Experiment in measurement of neutron flux  
4. Introduction to medical utilization (Boron-Neutron Capture Therapy, BNCT)  
5. Discussions on the results of control rod calibration and flux measurement  
6. Evaluation on Nuclear School activities by participants

There were 5 (five) experiment practices within 2-day Nuclear School; experiment or practice on reactor start-up and operation, experiment in power calibration, experiment in negative coefficient of temperature, experiment in control rod calibration, and experiment in measurement of neutron flux. Although there were 5 (five) experiment practices, the explanation for the theoretical background of the experiments were time consuming since the participants were mostly not familiar with nuclear science.

After the participants were introduced to history of Kartini reactor and its facility, they were introduced to radiation protection in which consists of basic knowledge on radiation interaction with matters including biological matters. Radiation dose as well as ALARA (as low as reasonably achievable) safety principle were also introduced here in order to give a picture how radiation is considered as safe for human being. For direct experience with reactor start-up and operation, participants were introduced to check-list during start-up, check-list on power rate, and check-list on
shutdown of the reactor. Power calibration experiment was introduced in order to determine power output of the reactor during operation. This experiment also provides description how fissile energy converted into sensible heat of reactor’s primary coolant. Experiment in negative coefficient of temperature provides description on how changes of reactor coolant’s temperature cause disturbance on reactivity. Experiment in control rod calibration provides description how nuclear reactor is controlled by what is called control rod. It determined control rod reactivity by plotting reactivity toward rod’s position ($\rho$ vs $h$ – graph). Experiment in neutron flux measurement gives description on how neutron flux, an important quantity in reactor operation, is measured. Here, neutron flux was measured by in-direct method by measuring activity of a detector material after irradiated in neutron field. The School also introduced medical use of nuclear technology, called BNCT (Boron-Neutron Capture Therapy).

Due to the limitation of space during Kartini reactor’s facilities visit, the participants were divided into two or three groups depending on the number of participants. Each group consists of 6-9 participants and 2-3 training group assistants. The assistants did not only give technical assistance during the experiments, but also more detailed explanation on theoretical background which was explained in the class prior to experiments.

3. Lessons learned from implementation
The last element of the Nuclear School was evaluation by participants. They were asked to fill a questionnaire regarding their feedback on the implementation of the School. Most of participants viewed the School as a good opportunity to improve their knowledge on nuclear science and technology since almost all of the participant had no prior knowledge on nuclear (reactor) science and technology. “It answered my curiosity at nuclear since my first impression on nuclear is about bomb” said a participant which reflects public misunderstanding on nuclear technology. Knowledge obtained in the School also said to be supportive to some students in understanding better chapters within subjects related with nuclear science and technology in the incoming semester.

By self-experiencing of experiments and entering reactor’s proximity, participants realized how safety precautions of working with radioactive materials including being in a nuclear facility are comprehensive and implemented strictly. A participant commented that the reactor facility is well-equipped and “…(my) safety is well-protected” said the participant.

Some participants expressed their appreciation to the classroom’s material presenters as well as experiments’ assistant for their patience during especially explanation of theoretical background on some experiments. This appreciation motivates other scientists to be involved more in such education and outreach activities. Previous study however revealed some scientists’ comments regarding involvement on education and public outreach such as: they do not have time, they leave it to those who are expert in education, or they think they are not good at public speaking or classroom presentation [6].

However, most of participants also criticized duration of the School as too short, so that it is ineffective to provide a picture of nuclear reactor science and technology. No (or a little) prior knowledge on nuclear (reactor) science and technology made the participants required longer time to understand certain basic knowledge on it while the training group assistants also required longer time and more explanation regarding some knowledge. It is suggested to organize this training in a routine basis gradually instead of in a time-to-time irregularly, so that the knowledge is delivered little by little and rather easier to acquire. Some participants also noticed that assistants became in a hurry explaining some information since the end of session is approaching. A participant suggested that Nuclear School is supposed to be held in 5 (five) days with the broader and more basic topics such as particle physics, and so on.

Some participants suggested that in the future, participants are also given an opportunity to operate the reactor as well as some instruments by themselves. During reactor start-up, operation, and shutdown the participants were only viewing and making some notes. They were not allowed to touch any panels although they were allowed to enter reactor’s control room as shown in figure 2(a). Similar
situation happened during the explanation of some measuring instrument in the vicinity of reactor as shown in figure 2(b). Those figures also show limitation of space for the experiment which is marked by participant’s comment: “The laboratory rooms were too narrow, so that it was difficult to see what the assistants is pointing out during explanation besides being not comfortable during experiments”.

![Figure 2. Participants visit reactor’s (a) control room, and (b) measurement instruments](image)

This suggestion designated the evidence how technology engagement is important in improving understanding on the technology. By directly engaging with a technology, people may be more understand how it works, what the benefits as well as disadvantages.

Some experiments require preparation not only equipment but also materials such as reagent and gas. A suggestion came up for early preparation prior to the experiments since an experiment was taking so much time because the assistant prepared nitrogen gas filling during the experiment instead of earlier filling before the experiment started.

4. Conclusion and recommendation

Nuclear technology is indispensable for Indonesia since it is not only for power generation but also for other industrial application. Therefore, nuclear-related science needs to be preserved by enhancing public campaign and education activities besides existing nuclear science’s formal education in universities. The other nuclear-related facilities, especially governmental institutions, also need to be functioned for public campaign and education outreach, at least similar activities with this Nuclear School. There are another 2 (two) nuclear reactors in Indonesia for research and material production purposes which are by facilities capable of implementation of education and public outreach similar to this Nuclear School.

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