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The Utility of Table-Top Exercises in Teaching Nuclear Security

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Abstract

In the emerging field of nuclear security, those responsible for education and training are constantly seeking to identify and engage with tools and approaches that provide for a constructive learning environment. In this context, this paper explores the nature and value of Tabletop exercises (TTX) and how they can be applied in the nuclear security context. On the one hand, the paper dissects the key components of the TTX and considers the broader pedagogical benefits of this teaching method. On the other hand, the paper draws lessons from the authors' experience of running TTXs as part of nuclear security professional development courses (PDCs) over the past six years. The paper finds that the TTX holds enormous benefit as a learning resource when developed as part of a comprehensive approach to nuclear security education.

I. Introduction

The final Communiqué of the 2016 Nuclear Security Summit stated that the threat posed by nuclear and radiological terrorism "remains one of the greatest challenges to international security, and the threat is constantly evolving" **[*1*].** This statement reaffirms the importance of putting in place measures to prevent, detect and respond to an act of nuclear and radiological terrorism and, consequently, to ensure that adequate resources are assigned to establish and maintain robust nuclear security measures worldwide. In its 2014-2017 Nuclear Security Plan, the International Atomic Energy Agency (IAEA) recognised human resources development as the "cornerstone of capacity building and sustainability of nuclear security skills" **[*2*].** While the number of states thought to possess nuclear weapons in their arsenal has not augmented since 2006, when North Korea conducted its first nuclear test, the number of states interested in starting or expanding civilian nuclear programmes has increased **[*3*].** This, along with the intensification of the use of radioactive sources in civilian applications, highlights further the need to educate and train the current and next generations of nuclear practitioners in security issues.

In 2010, King's College London (KCL), recognising this global need, conducted the first international nuclear security education Professional Development Course (PDC) with the support of the IAEA, through the International Nuclear Security Education Network (INSEN). The success of this initial event was the catalyst for a series of subsequent PDCs focusing on a range of nuclear security themes and

issues. In terms of structure, these PDCs normally consist of two one-week workshops, separated by a month of self-study and reflection. The week-long workshops are unique in that they seek to go beyond the conventional idea of simple information provision, and instead seek to marry essential knowledge in nuclear security with pedagogical best practice. Simply put, the PDC seeks to provide participants with subject matter expertise and the means to effectively diffuse this knowledge and understanding to their students.

This blended approach to nuclear security education has gained considerable momentum and KCL and others have organized scores of PDCs and related nuclear security workshops since 2010, targeting both international academics and industry practitioners. As part of this work, a wide variety of teaching methods have been employed, ranging from the traditional, instructor-led "lecture format" to more student-centric small-group sessions and TTXs. Of these approaches, the TTX has been demonstrated to be one of the most valuable resources, proving highly effective as a means of cultivating knowledge and understanding of nuclear security through experiential learning. The TTX also serves an important function as a means of grounding pedagogical theory and offering participants a testing ground for their teaching and training efforts. Against this background, and drawing on the KCL experience in designing, adapting and deploying TTXs as part of a broader train-the-trainer approach to nuclear security education, this paper will consider the role and value of TTXs in the nuclear security context..

II. Overview of Table-top Exercises

A brief examination of the academic literature on teaching methods reveals there is broad agreement on the goal of TTXs, namely to cultivate knowledge and understanding through experiential learning. However, there is considerable disagreement with regard to what constitutes a TTX. 'Game play', 'simulations' and 'group' or 'role play' exercises are just some of the descriptors used, often indiscriminately or even interchangeably **[*4*].** The distinctions here relate primarily to issues of scale, design, participation and deployment, all factors that merit consideration but ones that are beyond the scope of this paper. For the purposes of our discussions for the role and value of this method in nuclear security education, we define a TTX as a discussion-based interactive exercise during which participants engage with a hypothetical scenario in a controlled learning environment.

As the name suggests, a TTX is an exercise that can be, literally, performed "on top of a table" and one that usually does not require considerable financial resources to be designed and executed. Indeed, the primary investment on the part of the instructor is usually time – although admittedly, this may have a bearing on the financial aspect – and this varies according to the level of complexity pursued in the design process. The TTX is often used to ground and consolidate theoretical notions already delivered to the target audience by more conventional learning formats (e.g. lecture provision, essay writing etc). More than this, it provides for a holistic, practice based approach to thinking about real-life problems, their characteristics and their solutions. According to the Homeland Security Exercise and Evaluation Program (HSEEP), a TTX can be utilized "to enhance general awareness, validate plans and procedures, rehearse concepts, and/or assess the types of systems needed to guide the prevention of, prevention from, mitigation of, response to, and recovery from a defined incident" **[*5*].** The problems that participants assess are usually inspired by real life events but are hypothetical, in the sense that there is no involvement of real equipment or tools, and no physical displacement of the audience, distinguishing TTXs from simulations, which may be run at working facilities, using operational materials, and under real-life conditions. For instance, a TTX on the role of nuclear forensics in support of criminal investigations can be run in a modest classroom without the utilisation of any nuclear or radioactive material or expensive forensic laboratory equipment.

TTXs have long been used as a training method in various areas of activity. In the military context, for example, they have featured in programs of training and instruction for centuries **[*6*].** As well as being

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viewed as an inexpensive means of training new recruits on warfare-related subjects, TTX provide the military with a means of exploring strategy in practice and considering the implications and consequences of various courses of action in a particular theatre of conflict. In this regard, the nineteenth century represented a crucial turning point for the evolution of war-gaming TTXs. It was during this time that Baron von Reisswitz, a Prussian civil administrator with an interest in military history, conceived his famous *Kriegsspiel* (war-game). **[*7*].** Its revolutionary conceptual framework attracted considerable interest within the Prussian military circle, so much so that von Reisswitz was invited in 1812 at the Sanssouci Palace in Potsdam to present his work to King Friedrich Wilhelm III. **[*8*].** Meticulous topographical maps and porcelain troop pieces replaced out-of-scale generic geometrical installations, giving life to a much more realistic playing area, with a detailed set of rules ensuring a *rigorous* conduct of the game **[*9*].** In 1824, von Reisswitz presented the *Kriegsspiel* to his fellow officers and it is reported that one general was so impressed by its teaching value that exclaimed: "This is not a game! This is training for war!" **[*10*].**

More than 200 years have passed since the production of the original version of the *Kriegsspiel*, and various non-military institutions now consistently utilize TTXs for educational and training purposes – covering a wide range of topics, from emergency response during a pandemic outbreak to cyber security. The novelty here is thus not in the method, but rather in the effort to harness the pedagogical potential of TTXs for the benefit of nuclear security education. In the next section we will consider the design, implementation and assessment of a TTX, with specific reference to the various key roles and responsibilities of team members.

III. Deconstructing TTXs

A comprehensive TTX can be a complex exercise involving multiple actors engaging with a host of influencing factors in an intricate scenario that unfolds over a prolonged period of time. Yet for all the possibilities in this regard, integrating a TTX into the learning environment can be a relatively straightforward process. The success of a TTX depends on the extent to which organizers engage with three categories of action: planning and design; execution; and evaluation and assessment. It is important to note that these categories, outlined below, overlap considerably and should be considered as part of a cyclical rather than linear process. For example, planning does not end when execution begins but instead continues in the background with instructors constantly required to take stock of and respond to the decisions and moves made by participants.

A. Planning and Design

"By failing to prepare, you are preparing to fail", Benjamin Franklin once said **[*11*].** This is particularly apt when considering TTXs, given their unstructured nature and the emphasis placed on participant interaction. The success of a TTX is directly related to the level of planning and preparation devoted to the design of the exercise. In the context of a constructive alignment approach to teaching and learning – the dominant approach in higher education that aligns teaching activities with intended learning outcomes – this is the consideration of how the TTX will help support progress towards the pre-planned learning objectives of the broader course within which it is situated **[*12*].** For it may be that the TTX is not the appropriate means of achieving particular learning objectives and an alternative method might provide for a more productive learning environment.

A high level of organization is required from the outset, and to this end the KCL team adopted a collaborative approach to design and implementation. Ownership of the TTX design process was shared among a small team, with each member given specific responsibilities. From the instructor perspective, this approach created an environment where responsibility was shared among faculty members and each instructor had a stake in the exercise. In the KCL experience it was decided to limit design input to

members of faculty, those participating in the actual exercise had no input into this process as it was felt that this might unduly influence behaviour during the TTX. This said, it is worth noting that involving students in the design process can contribute to the construction of an inclusive learning environment and extend the learning benefits beyond the parameters of the actual exercise. The small size of the KCL team allowed for flexibility and speed in the design process: consensus was easy to reach and decisions were made quickly and implemented efficiently.

The available literature on TTX provides for a number of different "models" that can be followed, according to the complexity of the planned exercise and available resources **[*13*].** As a minimum, however, the following roles should be identified:

1. *Coordinator:* Responsible for organizing the exercise, define logical arrangement and liaise with;
2. *Facilitator:* Responsible for facilitating the running of the exercise and moderate discussions;
3. *Resource person(s):* Responsible for helping the facilitator in fulfilling its function and assisting in the conduct of the TTX; and
4. *Note taker (optional):* Responsible for keeping records of the key points of group discussions and any other elements relevant for assessing the TTX.

The division of roles and responsibilities presented above is only indicative and may not apply in every circumstance. For example, in situations where resources (financial and expertise) are limited the same person may fulfill; multiple roles (e.g. the coordinator can also play the role of the facilitator, and a resource person can also act as note taker).

The design and planning team is also responsible for deciding the number of participants partaking in the TTX. This is an obvious point to make, yet the number of participants and their level of knowledge relevant to the subject have a determining influence on the conduct and outcome of the TTX. An overly large group of participants may overstretch those responsible for design and implementation and thus dilute the quality of the experience for all involved. Conversely, if the group is too small, roles and responsibilities built in to the TTX may not receive the attention they deserve, or indeed be ignored. For the KCL exercises, the number of participants was capped at 25 with the design and implementation team numbering approximately five. This numerical balance was towards the upper end of the acceptable, but allowed the instructors to create a productive learning environment and a TTX that was sufficiently nuanced to involve all participants.

B. Execution

The second category of action is execution. With a detailed plan and a scenario that provides for a challenging and stimulating intellectual experience, the team of instructors moves to the implementation of the TTX. In the interest of the collaborative approach and shared ownership mentioned above, the coordinator who took the lead in the design phase now gives way to the facilitator who will assume responsibility for successful implementation.

It is during this stage that participants are briefed about the exercise. The facilitator must clearly explain both the purpose of the exercise and its nature. On the one hand, participants must be made aware of the specific learning objectives and how these fit within the broader course learning outcomes, while on the other hand, they must fully understand the parameters of the exercise and what is expected from them. In a group where participants are not known to each other, this stage may also require some time for team members to get acquainted.

To ensure the smooth running of an exercise, the facilitator must pay particular attention to time management and group dynamics in order to ensure that participants successfully complete all the exercise tasks. This is of central importance to the overall success of the TTX for at least two reasons. First, comprehensive TTXs often unfold over multiple phases where the actions taken during one phase have consequences for subsequent rounds. Second, given that TTXs constitute a form of complex learning, there is an inherent risk of cognitive overload. That is to say, unless given adequate time to engage with and process the information, tasks and challenges involved in the exercise, participants may "have difficulties learning because they are overwhelmed by the task complexity" **[*14*].** To address this issue, the KCL team conducted TTXs over a period of several days, the protracted timescale designed to allow participants of all levels to engage fully with the various tasks and phases involved.

During the execution of the TTX, a key task for the facilitator and colleagues is to monitor group dynamics and facilitate the expression of dissenting opinions, while reigning in strong personalities that may exist within groups. This is often challenging, particularly when TTXs are conducted within environments where there exists a strong hierarchy. In the KCL experience, for example, there have been occasions where senior individuals have led their team down a particular path while ignoring suggestions made by other team members. This form of group dominance can undermine the learning process and detract from the intended learning outcomes of the exercise. It is responsibility of the facilitator to address this behaviour and ensure that all participants have an opportunity to contribute.

While instructors must play a role in facilitating the exercise, ensuring engagement and providing direction if necessary, interventions must be handled with care. Clearly the management of intra-group relationships requires a good degree of emotional awareness. Yet, there are other challenges associated with instructor interventions. For example, while TTXs require a considerable amount of planning and learning objectives are established in advance, precise outcomes are often not pre-determined. Participants are normally given considerable room for maneuver within the parameters of the exercise. The goal here is to cultivate a process of active learning that sees tasks and problems engaged with on the participants' own terms. Substantive intervention in this context brings the risk of unduly influencing the decision-making process of participants and pushing groups down paths of enquiry that do not reflect participants' thinking.

Above all else, execution of a TTX requires flexibility on the part of the organizing team. As indicated above, the effort to provide intellectual space for participants and open alternative learning paths means that the complete instructor control over the progression and outcomes of the TTX is not possible. Consequently, the instructors must be prepared to deal with unexpected issues and the possibility of having to adjust elements of the TTX in response to the decisions made by participants. In short, the TTX provides instructors with a lesson in the art of managing uncertainty.

C. Evaluation and Assessment

From a learning perspective, there is little utility in designing and executing a TTX if participant performance is not gauged against the learning objectives driving the process. Whether the exercise is intended as a formative process or part of a summative assessment, the evaluation of participant performance is an integral part of the learning process. Yet assessing participant performance in a TTX is not a straightforward task given the more flexible structure and the ability of participants to choose various different courses of action. How then, should assessment be approached? Should the assessment be centered upon the performance of the group as a whole or the contribution of individual team members? If the former, how can the assessment process be tailored so as to distinguish between those who engage with the exercise and those who make little or no contribution and simply 'free-ride'? If the latter, is the team of instructors adequately

resourced to evaluate the performance of each participant? These are just some of the many questions raised by the question of assessment and evaluation. TTXs are a flexible teaching tool and, consequently, to generalize here is problematic and potentially counterproductive. Yet the literature does offer some approaches and suggestions that can be broadly applied.

For group assessment, possible approaches include **[*15*]:**

1. *80/20 grading:* Group assessment "is subject to five marking criteria one of which is individual contribution to group work. The product of the group work is graded by the tutor for four of the five criteria. The fifth is determined by the students themselves through the completion of a confidential questionnaire"
2. *Team-led individual: :* Participants "benefit from meaningful contributions to group work as a prelude to an individual submission. Teams of students produce a written submission upon which feedback but no grade is given by the tutor. Students then work alone to further develop the group work and produce an individual assignment".
3. *Examination follow-up:* with this method, "there are two pieces of assessed work for the module, a group project and an examination. Students receive identical grades for the product of their group work but a subsequent individual examination requires reference to, or detailed knowledge of, the group project".

These approaches can of course be adapted and used in combination. In terms of specific assessment tools it was found from the KCL exercises that post-workshop questionnaires, for example, commonly used in the group assessment approach, are particularly useful for testing participants' understanding of specific concepts/procedures/etc. A combination of closed and open questions provides instructors with considerable scope to probe participants' experience of the exercise. The same approach can also be employed before the TTX, providing instructors with a point of comparison with regard to participant knowledge and understanding. As mentioned above, one of the most important principles underpinning the design of a TTX is the importance of identifying learning objectives that will drive the exercise. Ultimately, then, the evaluation and assessment phase consider the extent to which these objectives have been achieved.

Of course, this student-focused assessment constitutes only one part of the evaluation process. Whereas "in the past we have seen assessment primarily as a means to measure the achievement of goals, and thus for certification and selection, there is now a belief that the potential goals of assessment are much wider and impinge on all stages of the learning process, and even beyond that" **[*16*].** An important element of the evaluation process relates to the need for the instruction team to spend time reflecting on the design and implementation of the exercise. Key questions here include: have the learning objectives been achieved? What challenges were encountered during the design and execution phases and how might these be offset or mitigated in future iterations? What new issues, if any, emerged from the exercise? What implications have these for the design of the exercise? This reflective process should form part of an ongoing cycle of refinement and adjustment, which contributes to strengthening the TTX as a learning tool.

IV. Educational Benefits of TTXs

As suggested in the above analysis, our view is that TTXs hold enormous value as a flexible and malleable teaching resource that can be used to promote active learning. At the most basic level, TTXs "relieve the tedium associated with more conventional modes of instruction" and "make learning a matter of direct experience" **[*17*].** This, in turn, contributes to increased motivation on the part of participants. In this regard, Dorn notes that "the most prominent claim is that use of simulation games [the definition of

which includes TTXs] will increase students' motivation to learn and their interest in learning" **[*18*].** A key factor here is the manner in which TTXs bring students on a journey from theory to practice. The TTX replicates, to some degree at least, real-world issues and/or conditions.

From a cognitive perspective, research has shown that TTXs enable students to engage with a subject 'in ways that traditional techniques like reading and lecturing do not', providing 'alternative learning paths to participants who do not respond well to conventional lecturing approaches'**[*19*].** A contributing factor here is undoubtedly the freedom that participants are given to solve exercise problems and tasks as they see fit. The path to learning here is more flexible and students are not bound by the constraints of other formats. Related to this point is the argument, put forward by Petranek et al., that TTXs stimulate students to "unconsciously process" a much wider range of information than traditional teaching methods, including 'facts, emotions, strategies, outcomes, relationships, feelings, and much more…' **[*20*].** Simply put, the TTX engages participants' cognitive functions from a variety of perspectives. This active engagement with the subject matter has been shown across a range of fields to stimulate deep, as opposed to surface learning **[*21*].**

Beyond the intellectual benefits, it is also important to note that TTXs encourage the development of broader skills on the part of participants. The group-work that normally forms a core element of the TTX demands a collaborative approach and the ability to work well with others, a skill that is highly prized in the workplace. At the same time, the flexible and less structured approach also cultivates a sense of individual responsibility, leadership skills and problem-solving. Crucially, these are all skills that do not naturally emerge from more conventional educational approaches such as the lecture format.

The above learning benefits are consistent with feedback on the use of TTXs gathered from the aforementioned PDCs organized by KCL. TTXs were consistently highlighted as a useful and valuable element of the course on post-PDC feedback evaluations, and it was clear that the vast majority of participants felt that their depth of understanding of a particular topic was significantly improved as a result of the TTX experience. This finding was reinforced by instructor observations, where it was clear that the TTXs encouraged comprehensive engagement with the various nuclear security-relevant issues at stake. This stands in contrast to the PDC sessions that were delivered in lecture/seminar formats where discussions tended to be less inclusive and provoked less enthusiasm. In addition the arguments put forward by the different groups during the TTXs demonstrated a nuanced and conceptual understanding of different nuclear security topics. However, this should be caveated by the additional observation that participants did utilize material covered in earlier sessions in the construction of their arguments. This simply shows that there remain merits to other teaching methods. Clearly, when constructing a broader course, a range of teaching methods should be employed in order to target students' different preferred learning styles.

V. TTX in Teaching Nuclear Security

Nuclear security is an extremely broad concept, encompassing the prevention, detection and response to malicious acts involving nuclear or radiological material, facilities and transports. As a consequence there are many different types of TTX exercise that can potentially be developed. Whether they are used to explore the interaction between different nuclear security stakeholders following an incident or as a means of informing security planning by the detailed consideration of a range of potential threats, TTXs offer a flexible resource that encourages active learning.

In the context of security planning, for example, it may be beneficial to develop a TTX that incorporates the use of red-teaming. This was practiced during the Cold War context, where 'US officers would take a Soviet i.e. red perspective' as a means of uncovering weaknesses in defense plans and systems **[*22*].** In a nuclear security-related exercise, a group of participants could be asked to take on the role of the

adversary and tasked with planning a malicious act, such as the theft of nuclear material from a facility. Constructing realistic attack pathways serves as a means of highlighting the weaknesses within a particular system. Another group (or even the same group in a subsequent phase) could then consider potential responses to any weaknesses identified. The value here is derived from the fact that nuclear security systems must be capable of responding to an intelligent adversary, that represents a dynamic and changing threat **[*23*].** Otherwise it can be easy for security planners to adopt a mind-set that is focused on solutions to specific technical problems, but that doesn't take into account the ability of adversaries to modify their behavior in response to security upgrades.

Perhaps the biggest obstacle facing those keen to integrate the TTX approach into their nuclear security education and training work is the time required to develop a scenario. Of course, an effective TTX can be developed relatively quickly around a few simple learning points. Yet there can be no doubt that a detailed TTX with the potential to fully engage and exploit the intellectual capabilities of participants requires considerable planning and design effort. The 'devil is in the detail' and a comprehensive TTX must contain enough detail to be perceived as credible by participants. Thankfully, there are a number of existing resources that can be used to support efforts on this front. The International Nuclear Security Education Network (INSEN) and others have developed hypothetical facility datasets, which can be readily used in nuclear security TTXs **[*24*].** These typically include information on the site layout, nuclear material holdings, personnel lists and existing security measures. After a particular dataset is selected then a decision must be made as to what type of TTX will be designed around it. Here there are many potential options. As discussed above a red-teaming type approach could be adopted where participants might be asked to play the role of an insider(s) and consider all the different ways in which the facility security systems could be negated. If done in a structured way, this could then be incorporated into a broader assessment of security system effectiveness for the hypothetical facility. Alternatively, instructors might decide to outline a specific security incident and ask participants to play the role of the on and off-site responders. This would then explore issues surrounding emergency preparedness and response, such as stakeholder coordination, public communication, segregation of duties and so on.

VI. Conclusion

It is clear from a pedagogical perspective that TTX offer a wide array of advantages when teaching nuclear security topics. First and foremost they place the student at the center of the teaching environment and by doing so stimulate flexible learning. They provide students with the freedom to construct knowledge for themselves, developing a cadre of critical thinkers and problem-solvers. This approach is consistent with a broader paradigm shift within Western and other higher education systems over the past 20 years, where the focus has shifted from that of passive instruction to active learning. Other benefits of TTXs include increased student motivation to learn and engage deeply with a subject. This has been clearly show in empirical studies and is consistent with what we have observed during PDCs run by KCL. TTXs also act as important vehicle for moving between theory and practice, providing a means of exploring how concepts stand-up in the real world. This is particularly relevant when considering nuclear security, as its implementation can differ widely from country to country.

While TTXs offer considerable educational benefits, these are not necessarily straightforward to access. Considerable care must be taken in the planning, execution and assessment of TTXs. In this article we have outlined a structured approach to this process, with an emphasis on identifying specific learning objectives at the outset and clearly aligning those to the performance and evaluation of the TTX. It is also important to recognize that TTXs must incorporate a level of complexity, which is reflective of the real world. As a consequence considerable resources, primarily time, may need to be allocated to the design stage of this process. There is a growing number of nuclear security relevant datasets that can serve to support these efforts, although it should be noted that these will require tailoring for use in different contexts.

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