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Training programs to counter current and emerging biological and chemical proliferation risks: themes, practices, and lessons learnt

Guest Editors: Tatyana Novossiolova, Tom De Schryver
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Editorial: Training on the mitigation of biological and chemical proliferation risks: insights into effective design, delivery, and implementation

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Chemical and biological security

International law prohibits chemical and biological weapons and their means of delivery establishing a framework of norms, standards, and rules to guarantee that under no circumstances these weapons are developed, produced, acquired, or used. The Biological Weapons Convention (BWC) and Chemical Weapons Convention (CWC) are important elements of this framework and share a common goal to counter the misuse of advances in life sciences, chemistry, and related fields. Both conventions rely on the general purpose criterion to ensure that biological agents, toxins, and chemicals are utilized solely for peaceful ends that benefit human, animal, and plant health, and the environment. The full and effective implementation of these conventions continues to face challenges. The re-emergence of chemical warfare tactics during armed conflict, as evidenced by the civil war in Syria and the ongoing war of Russia against Ukraine where the Russian armed forces have used riot control agents in violation

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of the CWC is an acute reminder that the international disarmament and non-proliferation architecture requires constant tending.[1] The deployment of chemical warfare agents as weapons for state-sponsored targeted assassinations tests the limits of the chemical prohibition regime and broadens the range of preconditions that need to be in place to ensure effective counter and defense against such threats. Recent attacks including the targeting of Sergei Skripal and his daughter, and the late Russian opposition leader, Alexei Navalny with "Novichok" and the poisoning of Kim-Jong Nam, a half-brother of North Korea's leader with VX highlight the complexity of investigating plots of this kind and the difficulties in holding their perpetrators accountable. And whilst the risk of chemical and biological terrorism might seem remote, the attempts of extremist groups to acquire poisonous substances, e.g. toxins and related manuals over the Darknet, and to attract followers and supporters with technical skills and knowledge that can be exploited for hostile purposes call for vigilance and proactive prevention.

To date, United Nations Security Council Resolution (UNSCR) 1540 remains the only international instrument addressing the risk of proliferation of chemical, biological, and nuclear weapons that is binding on all states. Adopted unanimously under Chapter VII of the UN Charter, this resolution contains provisions for the implementation of appropriate measures to guarantee the security of sensitive biological and chemical materials during storage, handling, transfer, transport, and use. UNSCR 1540 requires that states develop and enforce appropriate controls for the export and import of chemical and biological materials and related equipment to prevent their diversion for prohibited purposes. The resolution details what types of restrictive measures states need to adopt but it does not feature lists of materials and equipment that must be under control. Indicative control lists that cover dual-use biological and chemical materials and equipment, that is, materials and equipment which have legitimate application for peaceful purposes but can also be

[1] See, for example, First Report by the OPCW Investigation and Identification Team (IIT) on Ltamenah (Syrian Arab Republic) 24, 25, and 30 March 2017, S/1867/2020, 8 April 2020, https://www.opcw.org/iit/first-report-iit; Note by the Technical Secretariat: Second Report by the OPCW Investigation and Identification Team on Saraqib (Syrian Arab Republic) – 4 February 2018, S/1943/2021, 12 April 2021, https://www.opcw.org/iit/second-report-iit; Note by the Technical Secretariat: Third Report by the OPCW Investigation and Identification Team on Douma – 7 April 2018, S/2125/2023, 27 January 2023, https://www.opcw.org/iit/third-report-iit; Note by the Technical Secretariat: Fourth Report by the OPCW Investigation and Identification Team on Marea (Syrian Arab Republic) – 1 September 2015, S/2255/2024, 22 February 2024, https://www.opcw.org/iit/fourth-report-iit; Statement on Ukraine from the OPCW Spokesperson, 7 May 2024, https://www.opcw.org/media-centre/news/2024/05/statement-ukraine-opcw-spokesperson.

misused for biological and chemical weapon proliferation, have been agreed as part of voluntary international initiatives, such as the Australia Group (AG) and the Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies (WA).[2] The AG advances chemical and biological security by safeguarding trade and harmonizing the management of export control risks across countries. It sets up a comprehensive regime that comprises standardized licensing and screening requirements for the transfers of sensitive chemical and biological items. Items are categorized in Common Control Lists covering chemical weapons precursors, dual-use equipment, and related technology and software, and biological agents and toxins that affect human, animals, or plants. The scope of the WA is much broader covering munitions such as small arms and lights weapons, military armed vehicles, and aircraft, as well as multiple types of dual-use goods and technologies, including biological and chemical agents, and related equipment. With the exception of Russia and South Africa, all countries that participate in the Wassenaar Arrangement are also members of the AG.

The AG and WA criteria and requirements are incorporated in the EU regulation on the transfer of dual-use items which lays the foundations for the EU common export control system. To facilitate the in-depth implementation of the EU rules on export control and promote the adoption and internalization of security practices among stakeholders, the European Commission has recommended the development of internal compliance programs (ICPs) at industrial and academic entities that engage in export and transfer of dual-use items.[3] ICPs comprise an integrated set of institutional policies and procedures for due diligence to identify, assess, and mitigate risks related to the transfer of sensitive items. Training and awareness-raising are key elements of ICPs that enable practitioners to gain up-to-date knowledge of security risks and apply risk management principles and measures.

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[2] The Australia Group, https://www.dfat.gov.au/publications/minisite/theaustraliagroupnet/site/en/index.html; Wassenaar Arrangement, https://www.wassenaar.org/.

[3] Commission Recommendation (EU) 2021/1700 on internal compliance programs for controls of research involving dual-use items under Regulation (EU) 2021/821 of the European Parliament and of the Council setting up a Union regime for the control of exports, brokering, technical assistance, transit and transfer of dual-use items, 15 September 2021, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32021H1700.

Training for chemical and biological security

The primary goal of chemical and biological security is to prevent the intentional misuse of materials, knowledge, and equipment in ways that can threaten the health of humans, animals, or plants, or infrastructure. Key focus areas in chemical and biological security include international prohibition and disarmament regimes; counter-terrorism; export controls; physical security of chemicals and biological agents and toxins, and related technology, information, and equipment; and governance of research with dual-use potential. Chemical and biological safety, that is, activities which aim to prevent the inadvertent release of toxic chemicals and biological agents and toxins are complementary to realizing the objectives of chemical and biological security. Efforts to enhance chemical and biological security are cross-sectorial involving multiple stakeholders in different domains such as law enforcement, criminal justice, intelligence, defense, and civil protection. Chemistry and life science stakeholders in public sector, academia, and industry play an important role in strengthening the prevention of misuse of chemicals and biological agents and toxins. It is critical that these stakeholders have access to training opportunities that allow them to develop and expand their skillset, so that they have sufficient understanding of current and emerging security concerns and practical knowledge of using relevant strategies and tools for risk management. It is also vital that available training is aligned with the job description of professionals, so that the acquired knowledge and skills can be put into practice on a regular basis.

Developing impactful and high-quality training for biological and chemical security requires attention both to the content of training programs and the methods used for their delivery. It is essential that the content and methods for delivery correspond to the needs of the specific target audiences; that they achieve concrete learning objectives; and that they produce effective learning outcomes. Biological and chemical security training should aim at fostering core competencies that enable professionals to identify, assess, and manage security risks both within research facilities and in their interactions with clients, funders, collaborators, contractors, suppliers, etc. Standards are key to harmonizing the sets of core competencies that different professionals should demonstrate, and ensuring the quality of training programs. Active learning methods and strategies that put trainees at the center of training activities facilitate situational awareness and the acquisition of hands-on knowledge and skills which professionals can more easily transfer to and internalize into their everyday work. Sharing good practices through cross-disciplinary exchange and international and regional cooperation makes it possible to identify impactful and effective training strategies and

support their wide and tailored application across institutions and communities.

Design, delivery, and implementation of biological and chemical security training: overview of the JOSTC Special Issue

This JOSTC Special Issue addresses the design, delivery, and implementation of training programs for biological and chemical security by bringing together scholars and practitioners' perspectives. The papers in the issue cover two overarching themes. The first theme relates to the application of active learning methods for inculcating professional responsibility and practice-based competence and the role of such methods in contributing to an enriched training experience that encourages reflection. The second theme relates to the process of institutionalization of training activities to promote greater access to specialized knowledge in the areas of biological and chemical security. Several papers in the issue use examples from the field of nuclear security education. They bring specific methods and strategies to the fore that have been implemented for training on security issues.

Active learning in training design and delivery

Instructional strategies that require learners to solve problems, discuss, and reflect instead of just memorizing new information are commonly referred to as active learning techniques. Such strategies enable learners to make connections between different fields of knowledge and develop transferrable skills.

There are two papers in this special issue that provide concrete examples of the practical implementation of active learning principles when developing training programs. As such, these two contributions offer insights that may help practitioners in chemical and biological security education become more comfortable with the application of active learning principles in their own courses.

Tzinieris & Homan (2024) discuss the use of case studies and its advantages and in the context of non-proliferation education.[4] They propound that case studies have a long tradition in conveying message to

[4] Sarah Tzinieris, Zenobia S. Homan, "The nun who broke America's nuclear sanctum: the use of case studies in CBRN nonproliferation training", *Journal of Strategic Trade Control*, Special Issue, Vol. 2, (September 2024).

others. The authors offer insights into case study design and how such tools can be embedded in a training context. Essentially, the authors suggest that case studies have to present realistic but not necessarily real learning situations because realistic stories facilitate reflection and role-playing among learners. Drawing upon their practical experience, they also highlight limitations related to the application of case studies, including the need for developing materials that are tailored to the local context where the training takes place.

Parotte et al. (2024) draw thought-provocative lessons from their experience with serious gaming and how this active learning can be applied to facilitate reflection and deliberation on complex issues of social significance.[5] Serious games allow for an interdisciplinary engagement and can be particularly useful in the field of chemical and biological security which cuts across several areas of scholarship and professional practice. The authors show how uncertainty can be introduced in games by elements of randomness, and how controversies can be introduced by creating hypothetical complex scenarios that lead to dilemmas and require trade-offs. Some of the lessons that they describe are transferable outside the gaming context, whereas others are more relevant to the specific serious gaming context. A first general takeaway relates to the use of jargon in a training program and how it can serve as conversation-starter between learners about the potential meaning of jargon. Second, the authors address the need to manage the timing of expert interventions carefully. In particular, they recommend that learners should try to work through controversies on their own first before consulting an expert.

Institutionalization of training activities

Whereas the first theme in this special issue focuses on the application of active learning principles, the next three contributions discuss the development of formal processes for training delivery. The establishment of university curricula, producing training resources, and fostering professional networks for community learning are relevant mechanisms that contribute to the institutionalization of chemical and biological security education.

Zanders (2024) describes the rationale, the context, the design, and implementation process of a CBRN master program developed within the

[5] Céline Parotte, Nathan Flore, Sacha Frenay, "Training to embrace uncertainties? The 'Pathway Evolution Process' serious game for assessing toxic waste program", *Journal of Strategic Trade Control,* Special Issue, Vol. 2, (September 2024).

EU- supported Targeted initiative.[6] The EU Targeted Initiative on dual-use export controls aims to engage the academic community in CBRN-related fields of knowledge with the management of risks relating to technology transfers. Introducing university curricula such as a master program can promote sustained attention to chemical and biological security risks at the community level. A master program allows creating a network of alumni and professionals and ensures that the message gets across.

Udum (2024) discusses the role of professional networks in promoting security education.[7] She shows that International Nuclear Security Education Network (INSEN) is an important piece in the nuclear security puzzle and shares her first-hand experience of being involved in INSEN activities. Supported by the International Atomic Energy Agency (IAEA), INSEN creates informal and friendly learning opportunities for professionals in the field of nuclear security education allowing members to interact and share knowledge and experience. INSEN members develop training materials, design and implement training courses and curricula, and engage in advocacy and outreach on the value of promoting nuclear security competence among relevant practitioners.

Shang et al. (2024) report on a development of a recent educational resource in the field of biological security in the form of an edited textbook with contributions from scholars, experts, and practitioners from around the world.[8] Building upon this experience, the authors discuss how the establishment of a professional network—International Biological Security Education Network (IBSEN), that draws on the INSEN model, can result in broadening the access to biological security education.

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[6] Jean Pascal Zanders, "Building a culture of responsibility: education for disarmament and non-proliferation", *Journal of Strategic Trade Control*, Special Issue, Vol. 2, (September 2024).

[7] Şebnem Udum, "The role of education in nuclear security compliance: the International Nuclear Security Education Network as a good practice", *Journal of Strategic Trade Control,* Special Issue, Vol. 2, (September 2024).

[8] Lijun Shang, Weiwen Zhang, and Malcolm Dando, "Addressing the biological security educational gap", *Journal of Strategic Trade Control*, Special Issue, Vol. 2, (September 2024).

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The nun who broke America's nuclear sanctum: the use of case studies in CBRN nonproliferation training

Sarah Tzinieris, [*] *Zenobia S. Homan*[**]

Abstract

The article examines the use of case studies to support training programs focused on the nonproliferation of chemical, biological, radiological, and nuclear (CBRN) materials and equipment. It argues that educational methods that induce 'deep learning' help to impart a more comprehensive and meaningful understanding of the subject matter. CBRN-focused training and development courses have seen substantial growth in recent years, reflecting an increasing recognition of the major risks posed by CBRN proliferation. However, there remain obstacles to implementing such programs, both due to the limited resources available and the need to educate a diverse and global-dispersed community of practitioners. Pedagogical methods that place the trainee at the center of the teaching process are known to induce a deeper understanding and develop critical thinking skills. Case studies are particularly effective in this endeavor as they offer a dynamic means of grounding complex or intangible concepts into relatable, realistic situations. Case studies also induce a storytelling quality, a mnemonic device that helps learners recall large amounts of information and for long durations. The article argues however that the selection of case studies requires improvement to reduce bias. There is a current lack of

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diversity in available case studies, and for too long, case studies have tended to reflect Western priorities and may not be easily relatable to non-Western audiences. Lastly, the article emphasizes that the utility of the case study approach comes down to how effectively they are curated within a broader curriculum as well as how well they are taught, which requires skillful facilitators who can cultivate a dynamic and engaging discussion.

Keywords

Case approach, case studies, CBRN, CBRN training, deep learning, nuclear security, professional education, Y-12.

Introduction

In July 2012, an 82-year-old Catholic nun and two other anti-nuclear protesters broke into the Y-12 nuclear weapons site in Tennessee, which until then was considered America's most secure nuclear facility. Sister Megan Rice and her two co-defendants were later convicted of sabotage and given custodial sentences of between three and five years. During the break-in, the activists cut through three security perimeters to reach the site's nuclear storage bunker, recently constructed to the tune of half a billion US dollars.[1] On reaching the bunker, which stored much of America's weapons-grade uranium, they daubed the walls with biblical references and human blood.[2]

Why is this story so compelling? It is a case study often used in the training of nuclear security professionals. Tapping into the minds and emotions of people through storytelling is one of the most effective ways to help them improve memory and retain facts, especially when stories are as captivating as that involving Sister Megan. Reader, if you were to close your eyes now, almost certainly you would recall that this story is about an elderly nun breaking into a nuclear site; most probably you would also remember it was supposed to be a very secure nuclear site and that the activists used blood during their protest; if you were concentrating hard you would recall that they cut through multiple security perimeters, were convicted of sabotage, and the site cost half a billion dollars to construct.

A case study is an account or narrative that provides detailed information on how a person, group, or thing develops in order to demonstrate general principles.[3] Case studies are essentially stories that present realistic and contextually rich situations, and they often involve a dilemma or problem to resolve.[4] Employed in both teaching and research contexts, it is this critical thinking element that defines the case study approach. In so doing, case studies offer a dynamic means of grounding complex or intangible concepts into realistic situations that people can relate to. In a teaching environment, trainees or students are able to identify the parameters of an issue and then go on to evaluate the various courses of action. Rather than focusing on generic theories in isolation, they can make decisions

[1] "Nun, 84, sentenced to three years in jail for nuclear break-in", *The Guardian*, February 19, 2014, https://www.theguardian.com/world/2014/feb/19/nun-jailed-break-in-nuclear-plant.
[2] Eric Schlosser, *Gods of Metal* (Penguin, 2015).
[3] Based on the definition of 'case study' provided by the Cambridge Dictionary, online.
[4] "Case Studies", Eberly Centre, Carnegie Mellon University, accessed October 16, 2023, https://www.cmu.edu/teaching/designteach/design/instructionalstrategies/casestudies.html.

based on analyzing all of the information available.[5] In these conditions, trainees or students are able to engage with the nuances and complexities of any given situation, probing the implications of different courses of action.[6]

This article examines the use of case studies to support training and development programs focused on the nonproliferation of chemical, biological, radiological, and nuclear (CBRN) materials and equipment. CBRN-focused training and development programs have seen substantial growth in recent years, reflecting an increasing recognition within the international community that CBRN materials falling outside regulatory control pose significant safety, security, and environmental risks. These issues have long been known but the adoption of UN Security Council Resolution (UNSCR) 1540 in 2004 has created greater global awareness of the risks.[7] Notably, UNSCR 1540 requires states to implement appropriate measures to ensure the security of 'nuclear, chemical or biological weapons', with specific provisions on physical protection, material accountancy and control, and border controls.[8] Thus implementing CBRN training is an obligation that all states should fulfill, and this extends to aligning their national regulation in the CBRN sphere to international legal provisions.

However, there remain obstacles to implementing such training, both due to the limited resources available and the need to educate a diverse and global-dispersed community of practitioners. Pedagogical methods that place the trainee or student at the center of the teaching process are known to induce a deeper understanding of the subject matter, and case studies are particularly effective in this endeavor. They also induce a storytelling quality, a mnemonic device that helps learners recall large amounts of information and for long durations. It is this 'deep learning' that imparts a more comprehensive and meaningful understanding of the subject matter.

The article is divided into three sections: the first discusses the theoretical underpinnings of the pedagogy for case studies; the second provides some practical information on teaching implementation; and the third

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[5] Edwin C. Leonard Jr. and Roy A. Cook, "Teaching with Cases", *Journal of Teaching in Travel & Tourism,* 10(1) (March 2010), p. 96.

[6] Ellen Schall and Thomas Gilmore, "Staying Alive to Learning: Integrating Enactments with Case Teaching to Develop Leaders", *Journal of Policy, Analysis and Management* 15(3) (1996), pp. 444-456.

[7] Wyn Q. Bowen, Matthew Cottee, and Sarah Tzinieris, "Evolution of Global Nuclear Security Governance", in Christopher Hobbs, Sarah Tzinieris, and Sukesh Aghara, eds., *The Oxford Handbook of Nuclear Security* (Oxford: Oxford University Press, 2023).

[8] UN Security Council, Security Council Resolution 1540 (2004), April 28, 2004, S/RES/1540 (2004).

examines the limitations of case studies but argues these are possible to overcome with sufficient resources and planning. In writing this article, we, the authors, conducted a comprehensive literature review and revisited empirical findings from CBRN nonproliferation training that we delivered from King's College London. Ultimately, it was found that experiential teaching methods in general are preferable to traditional passive learning formats so long as the trainee is at the center of the teaching process. Moreover, although case studies are only one of several types of experiential teaching methods, they are the most expedient to achieve positive learning outcomes—especially when resources are limited. We argue however that the selection of case studies requires improvement to reduce bias. For too long, case studies have tended to reflect Western priorities and may not be easily relatable to non-Western audiences. We also emphasize that the utility of the case study approach comes down to how effectively they are curated within a broader curriculum as well as how well they are taught, which requires skillful facilitators who can cultivate a dynamic and engaging discussion.

Case studies as a pedagogical tool

In recent decades, there has been a profound shift in the delivery of teaching within the higher education sector. Driven by a desire to improve the way in which students learn, education professionals have sought to develop teaching methods that induce 'deep learning', with the aim to impart a more comprehensive and meaningful understanding of the subject matter.[9] The pedagogy literature charts these new developments in teaching methods, sometimes differentiating between the traditional 'instruction paradigm' and the more recent 'learning paradigm', this distinction being first proposed by Robert Barr and John Tagg in 1995.[10] The instruction paradigm describes what was historically the dominant approach to teaching: a passive format whereby instructors, often subject matter experts, deliver a lecture to a large group of students in a one-way exchange of information. Students are expected to assimilate a significant amount of information, usually with a view to replicating this information, or parts of it, through an assessment process such as an end-of-course examination.[11]

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[9] Jackie Lublin differentiates between 'deep', 'surface' and 'strategic' approaches to learning; see "Deep, Surface and Strategic Approaches to Learning", Centre for Teaching and Learning, University College Dublin, 2003.

[10] Robert B. Barr and John Tagg, "From Teaching to Learning: A New Paradigm for Undergraduate Education", *Change: The Magazine of Higher Learning,* Vol. 27, Issue 6 (1995).

[11] Christopher Hobbs and Matthew Moran, "Developing Educational Courses in Nuclear Security: A Handbook", King's College London, 2014.

The learning paradigm, by contrast, places the student at the center of the teaching process. The aim is for students to derive a deeper understanding of the subject matter and develop critical thinking skills. The learning paradigm recognizes that a flexible combination of teaching methods, dependent on the specific subject matter, is an effective way to engage students. This approach also attaches significance to assessment and feedback throughout the period of learning, rather than the examination element being viewed as a standalone product at the end of a program.[12] Case studies complement the learning paradigm approach well through their emphasis on placing the student at the center of teaching to induce problem-solving and deep learning. Various scholars have shown that of all the classroom methods employed, the use of case studies is typically the most effective for developing critical-thinking skills.[13]

Case studies have been used in teaching for centuries. It is difficult to compose a precise history because it likely pre-dates the invention of writing. Epic tales such as *Gilgamesh* and the *Odyssey* were used to immerse audiences in a myriad of life lessons,[14] and ancient philosophers like Aristotle and Plato have acknowledged the value of narrative demonstrations.[15] Case studies as a formal teaching method, however, first appeared in American universities in the late nineteenth century.[16] In particular, the pioneering efforts of Dean Christopher Columbus Langdell of the Harvard Law School encouraged students training to become lawyers to interrogate and discuss previous legal cases. The objective was "to generalize particular decisions into broader understandings of the principles of law."[17]

Despite initial skepticism of Langdell's approach, the method gradually spread to other law schools in the US and then subsequently to other countries. Concurrently, the development of a new school focused on business was under discussion within the university: the modern-day Harvard Business School, which opened its doors in 1908. From the outset, its curriculum focused on practice and the instructional method

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[12] Hobbs and Moran, "Developing Educational Courses in Nuclear Security".
[13] Beryl C. McEwen, "Teaching Critical Thinking Skills in Business Education", *Journal of Education for Business,* 70(2) (July 2010), pp. 99-103; Leonard and Cook, "Teaching with Cases", p. 96.
[14] Maria Tilk, "Educational Narratives as a Pedagogical Paradigm: the Epics of Homer", *Acta Paedagogica Vilnensia,* 32 (January 2014), pp. 44-58.
[15] Elizabeth Trott, "Philosophy as Storytelling", *Ultimate Reality and Meaning,* Vol. 35, Issue 3-4, (September -December 2012), pp. 190-203.
[16] Katherine K. Merseth, "The Early History of Case-Based Instruction: Insights for Teacher Education Today", *Journal of Teacher Education,* Vol. 42, Issue 4 (1991), p. 243.
[17] Merseth, "The Early History of Case-Based Instruction", p. 243.

was a case approach within classroom discussion. The Harvard case method has been so influential it can be understood as a whole sub-set of the field, with its emphasis on role-play and Socratic debate.[18]

Since then, case studies have been used in higher education for over 150 years—most widespread in the disciplines of law, business, and medicine.[19] In recent decades, educators from a variety of academic disciplines and other educational contexts have recognized their utility as a pedagogical tool, and case studies have been adapted for use not only in academia but in industry, including in sectors that deal with CBRN issues. As well as in teaching, the case study approach can be used in a research context, although in practice these mediums are interlinked. Case study research can be applied to conduct pilot research and even to develop new theories or refine existing ones.[20] In a research context, the utility of case studies comes from being able to test complex issues in real-life settings.

The academic literature on pedagogy employs various terms to describe the use of case studies in teaching: case study methodology, case study pedagogy, case study method, case study instruction, case discussion, or case reading.[21] Related fields also include the study of narrative and the study of memory. At its heart, the case study approach is about employing dynamic and innovative methods to engage students or trainees on a particular topic.[22] After all, the storytelling quality of many case studies acts as a mnemonic device that aids information retention and retrieval in the human memory for better understanding. Classic mnemonic devices are associated primarily with memorization (e.g., the alphabet song)—focusing on the cognitive process of remembering. However, the goal is always to help people encode, store, and make sense of information—resulting in meaning-making.

Memory is not only a function of the human brain; it also has a social dimension.[23] Key factors that contribute to the development of memory

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[18] For more details on the HBS Case Method, see "The HBS Case Method", Harvard Business School, accessed October 16, 2023, https://www.hbs.edu/mba/academic-experience/Pages/the-hbs-case-method.aspx.

[19] Tricia Mclam and Marianne Woodside, "Using Case Studies: An International Approach", *International Education,* Vol. 34, n. 2, (2005), pp. 36-45.

[20] Johan Malmqvist et al., "Conducting the Pilot Study: A Neglected Part of the Research Process?" *International Journal of Qualitative Methods,* Vol. 18, no. 1 (2019).

[21] Sarah Gravett, Josef de Beer, Rika Odendaal-Kroon, and Katherine K. Merseth, "The affordances of case-based teaching for the professional learning of student-teachers", *Journal of Curriculum Studies,* Vol. 49, No 3 (2017), p. 372.

[22] Vicki L. Golich, Mark Boyer, Patrice Franko, and Steve Lamy, "The ABCs of Case Teaching", Institute for the Study of Diplomacy, Georgetown University, 2000, p. 32.

[23] Maurice Halbwachs, *On collective memory* (Chicago: Chicago University Press, 1992).

are motivation, attention, and conscious decision-making.[24] In other words, you are unlikely to remember something you did not pay attention to and do not care about. One of the reasons that narratives, storytelling and, indeed, case studies are so effective in learning is that they are deeply rooted in culture, encompassing social behavior, institutions, and norms that people are familiar with.[25] Case studies almost inevitably link to beliefs, views, and values (in the instructor, the trainee, and the characters in the case itself). It is difficult not to remember Sister Megan—whether that is due to her sabotage, activism, faith, or even gender.

A criticism often levied at higher education is that it 'is too theoretical, or not sufficiently practice focused'.[26] Case studies present an alternative to more passive teaching formats such as speeches and lectures, where a speaker imparts information to others in a unilateral exchange. Case studies bring unique value by bridging the perceived gap in education between theory and practice, sometimes termed the 'theory-practice predicament'.[27] With this approach, students are expected to analyze a realistic situation, apply prior concepts, knowledge, or personal experiences, and then produce recommendations for actions or draw logical conclusions. Through the process, case studies help to ground theoretical concepts in practice through the application of critical thinking.[28]

Case studies also provide a context in which uncertainty and nuances can be probed—not dissimilar to the 'real world'—but with the advantage that poor judgments or flawed decisions have no real-world consequences.[29] They also give students practice in identifying the parameters of a problem, recognizing and articulating positions, evaluating courses of action, and arguing different points of view. Furthermore, case studies are often conducted in a group setting, thereby encouraging students to develop communication, interpersonal, and teamwork skills. Underscoring the importance of 'soft skills', the 2023 World Economic Forum report makes the point that despite the predicted expansion of

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[24] Tommy Oaks, "Storytelling: A Natural Mnemonic. A Study of a Storytelling Method to Positively Influence Student Recall of Instruction", doctoral dissertation submitted to the University of Tennessee, Knoxville, 1995.

[25] Qi Wang, Qingfang Song, and Jessie Bee Kim Koh, "Culture, Memory, and Narrative Self-Making", *Imagination, Cognition and Personality,* Vol. 37, Issue 2 (2017), pp. 199-223.

[26] Gravett et al., "The affordances of case-based teaching", p. 369.

[27] Gravett et al., "The affordances of case-based teaching", p. 370.

[27] Merseth, "The Early History of Case-Based Instruction", p. 379.

[28] Christopher Hobbs and Matthew Moran, "Insider Threats: An Educational Handbook of Nuclear & Non-Nuclear Case Studies", King's College London, 2015, https://www.kcl.ac.uk/csss/assets/insider-threats-handbook.pdf.

[29] Merseth, "The Early History of Case-Based Instruction", p. 379.

automatic and artificial intelligence (AI) in the workplace, human skills like creativity, collaboration, empathy, and communication will continue to be highly valued by employers.[30]

Regarding their content, case studies vary widely but the pedagogical literature sometimes distinguishes between two types: 'retrospective' or 'narrative'; and 'decision-forcing'.[31] In a retrospective or narrative case study, a comprehensive description of events is presented, "complete with multiple actors, contending interests, and the *real* outcome."[32] Students are made aware of the sequence of events leading up to a final outcome and may be asked to determine if a 'better' solution was possible. For example, the entire account of Sister Megan and her accomplices infiltrating the Y-12 facility is told, and students are asked to reflect on this. In a 'decision-forcing' case study, the final outcome is not made available; rather, students are asked to identify and then assess the range of possible options to be actioned.[33] For example, students are told only about the infiltration of Y-12, but not of the guard force's response or any subsequent security policy changes. The latter type of case study confers a variety of benefits, depending on the point of 'deployment'.[34] Introduced at an early stage, a decision-making case study can stimulate creative thinking ahead of theoretical principles being introduced; at a later stage, such an approach can enable students to use their knowledge to deal with the complexities of real-world problems. In sum, there are multiple benefits of employing case studies as well as multiple ways of doing so, and it is useful to now consider ways in which they can be implemented in the context of CBRN training, so they have the greatest impact.

Implementing the case approach in CBRN training

Training and development programs focused on the nonproliferation of CBRN materials and equipment have seen substantial growth in recent years, reflecting an increasing recognition by the international community of the substantial risks posed by CBRN proliferation. Despite the CBRN lexicon, the field is in fact extremely wide-ranging and covers aspects as diverse as chemical weapons attacks in Syria, the use of nuclear forensics to locate radiological materials out of regulatory control, and the anthrax attacks in the US following the events of 9/11. What is more, each of the

[30] "Future of Jobs Report 2023", World Economic Forum, May 2023, https://www3.weforum.org/docs/WEF_Future_of_Jobs_2023.pdf.
[31] Hobbs and Moran, "Insider Threats".
[32] Golich et al., "The ABCs of Case Teaching", p. 1.
[33] Golich et al. "The ABCs of Case Teaching", p. 1.
[34] Geoffrey Chapman et al., "Security Culture: An Educational Handbook of Nuclear and Non-Nuclear Case Studies", King's College London, 2017.

four aspects—chemical, biological, radiological, and nuclear—is governed by different national and international regulatory regimes, with separate legal bases and different sources of best practice information.

The CBRN concept has deep historical roots, with the use of unconventional agents to inflict harm and death documented as early as writing itself.[35] However, the salience of the CBRN security issue came to wider intentional notice following the 9/11 attacks. The notion that non-state actors could initiate mass casualty terrorist attacks prompted a wave of policy entrepreneurship to mitigate the threat of CBRN proliferation, including funding for the training of security and safety professionals. From an early stage, it was also recognized that threat reduction efforts would only be effective and sustainable if those implementing security measures understood the broader issues at stake—namely, the nature of the threat, the maintenance and testing of security systems, the critical importance of a strong security culture and the range of potential adversaries, especially the threats posed by 'insiders'. This section examines how the case study approach has begun to be implemented in training and teaching in the CBRN nonproliferation field. Here, it is argued that case studies are highly effective means to activate awareness and cognition of CBRN issues, and they can be further supplemented and enhanced with other training methods and interventions.

The training context

The past few decades have seen a shift in approach within higher education and professional training from that of passive instruction to active learning. Here, studies from a wide variety of fields have demonstrated the benefits of experiential and more flexible learning where students are placed at the center of the teaching environment.[36] This approach offers students the freedom to engage deeply with a subject, develop their own critical thinking skills, and apply these to complex problems. It also recognizes that students will have different preferred learning styles.[37] Consequently, applying a variety of teaching

[35] Zenobia S. Homan, "Unconventional Warfare in the Ancient Near East", *Social Sciences & Humanities Open,* Vol. 8, Issue 1 (2023).
[36] Robert B. Barr and John Tagg, "From Teaching to Learning: A new Paradigm for Undergraduate Education", *Change: The Magazine of Higher Learning* 27, no 16 (1995), p. 13.
[37] Neil D. Fleming and Colleen Mills, "Not Another Inventory, Rather a Catalyst for Reflection", Professional and Organizational Development Network in Higher Education, 1992, p. 137.

methods and catering to the different learning styles within a group can serve to motivate students and encourage deeper learning.

Training and development have taken a variety of forms. A popular format for industry personnel working in the CBRN field has been the use of workshops, focused on training early- and mid-career professionals. Workshops are designed to complement states' existing efforts to improve the protection of CBRN materials and equipment. The flexible approach enables instructors to showcase best practice guidance, share experiences in implementing other CBRN-related programs, and consider lessons learned, in addition to employing case studies. The workshop format tends to employ subject matter experts (SMEs) to disseminate information in a focused, educational environment. Trainers adapt the case studies they select to their audience. For example, in a workshop focusing on insider threats, they might use the case of Rodney Wilkinson's infiltration of Koeberg's Nuclear Power Plant; while working as a laborer on the plant's construction, Wilkinson planted four bombs to protest apartheid.[38] Nevertheless, the case study does not need to have an explicit CBRN dimension to have the desired impact, just as long as it is specific to the issue area being taught. As an example, cases from aviation can equally reveal important insights on countering insider threats. The case of the German Wings murder-suicide crash can be used to broadly address the issue of unfitness for work in any organizational structure.[39]

Developing CBRN nonproliferation training for an international audience is not a simple endeavor. There exist significant complexities in terms of stakeholders, national contexts, regulatory systems, and the operating environments in which CBRN materials are employed. One of the challenges is conveying the criticality of this undertaking to governments and other key international stakeholders when historically nuclear security and chemical security—but not radiological security or biological security—have been perceived as more salient. To be effective, training also needs to focus on reaching participants of diverse organizational and cultural backgrounds. To this end, trainers around the world are now making an effort to diversify CBRN case study materials. Where previously they heavily relied on cases drawn from the US, owing to the dominance of the Harvard case method and others, but which may not

[38] Jo-Ansie van Wyk, "Nuclear terrorism in Africa: The ANC's Operation Mac and the attack on the Koeberg Nuclear Power Station in South Africa", *Historia* 60, no 2 (2015).
[39] Geoffrey Chapman et al., "Radicalisation and Preventative Measures: An Educational Handbook of Insider Threat Case Studies", CSSS Occasional Paper Series, King's College London, 2018, https://kclpure.kcl.ac.uk/portal/files/124516397/Radicalisation_Preventative_Measures_Handbook.pdf.

always be relatable, cases are now being assembled that draw from other regions.[40] For example, King's College London recently released a case study handbook authored by researchers from India and Pakistan that explores nuclear and radiological security in a specifically South Asian context.[41] This includes case studies that relate specifically to the milieu, including the agricultural sector in this region, nuclear medicine facilities, the development of new cyber security policies, and the impact of political misinformation on nuclear security.

Recognizing these challenges, it is argued that the theoretical concepts of CBRN nonproliferation education can be most effectively disseminated through pedagogical tools that both encourage interaction between instructors and trainees, and ground concepts in the real-world situations of the trainees themselves. The overarching training environment should also be designed with the recognition that trainees may hail from a wide variety of backgrounds—national, academic, and vocational. Where possible, the material should be relevant and applicable to—just to use hypothetical examples—a worker from an oil company operating in Nigeria engaged in well logging, a cancer nurse in Italy using radiotherapy, or a university researcher working with biohazardous materials in India. Consequently, the curriculum should employ an interdisciplinary approach to ensure that wide-ranging contexts are covered. It is also crucial that learning materials are shaped by international guidance—such as that produced by the International Atomic Energy Agency (IAEA) and the Organisation for the Prohibition of Chemical Weapons (OPCW)—as well as other sources of international best practices. In sum, case studies are most likely to be effective when cases are tailored to a trainee's context, although a flexible approach is necessarily required when dealing with a diverse audience (such as in an international workshop setting).

Case studies in a workshop setting

The workshop format makes an obvious pairing with the use of case studies, which are now widely recognized as an effective way to link theory with practice and to develop critical thinking skills.[42] Here, real-life case studies involving the proliferation of CBRN materials and devices

[40] To put this in context, Harvard Business School earned US$16.7 million from selling case studies in 2022; see Harvard Business School, 2023, 2022 Annual Report, 24, https://www.hbs.edu/about/annualreport/2022/HBS-Annual-2022.pdf.

[41] Zenobia Homan and Amelie Stoetzel, eds., "Exploring nuclear and radiological security in South Asia: A case study handbook", CSSS Occasional Paper Series, King's College London, 2022, https://www.kcl.ac.uk/csss/assets/exploring-nuclear-radiological-security-south-asia.pdf.

[42] McEwen, "Teaching Critical Thinking Skills in Business Education", p. 96.

can be presented in a 'retrospective' manner with trainees tasked with assessing the motivations and actions of the 'adversary', before identifying the facility's security failings.[43] Trainees might also be encouraged to consider broader lessons from particular cases and transpose them into their own organizational contexts. For example, the case of Sister Megan is relevant to CBRN training in terms of what it tells us about security culture. As such, a trainer might ask, "Why do you think the first responder acted in the way they did?", "What does this case tell us about the importance—and difficulties—of managing and motivating a guard force?", and "What does it tell us about the importance of the human factor in the design, operation, and maintenance of physical protection systems?".

To explore the practical implementation of CBRN nonproliferation measures across various organizational environments, the pedagogical methods employed should be designed to engender active participation and the sharing of experiences. This is especially effective when the workshop participants consist of practitioners hailing from different organizational backgrounds (such as from across government, regulatory bodies, operators, and so on[44]). Tapping into this source will enable trainees to offer unique viewpoints as well as considerable practical experience. A flexible approach to the use of case studies enables a skilled instructor to pursue such opportunities, as well as leverage from "teachable moments" that can emerge through classroom discussion.[45] The aim here is to guide trainees towards mutual discovery and enable learning on multiple levels. The collaborative nature of working in groups to interrogate case studies creates a more relaxed environment and this can stimulate greater reflection and self-observation.[46]

Despite the obvious benefits of flexible and experiential learning, however, the more traditional lecture format (i.e., the instruction paradigm) may remain relevant to some aspects of a CBRN nonproliferation workshop. This format—involving an SME speaking to a group in a unilateral exchange—is an effective method when there is a requirement to transmit

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[43] King's College London has developed a number of case study handbooks for integration into education and training programs; see https://www.kcl.ac.uk/csss/training.

[44] This is the typical diverse makeup of trainees in the CBRN workshops delivered by King's College London.

[45] "Teaching by the Case Method: Case Method in Practice", Christensen Center for Teaching & Learning, Harvard Business School, accessed October 16, 2023, https://www.hbs.edu/teaching/case-method/Pages/default.aspx#:~:text=Chris%20Christensen%20described%20case%20method,real%2Dworld%20problems%20and%20challenges.

[46] "Teaching by the Case Method", Christensen Center for Teaching & Learning.

a significant amount of information in a short period of time. Here, lectures can be used largely to convey key concepts rather than to focus on the implementation of measures. There may be a role for the instruction paradigm even in a workshop setting, for instance, to set out high-level concepts when a topic is first introduced to trainees in a large group setting before instructors then switch to the learning paradigm. Understanding how these formats can be used in complementary ways reflects a skillful curation of the curriculum.

Ensuring sustainable outcomes

The issue of sustainability and long-term impact is critical in any educational or training activity. Given the technical nature of CBRN nonproliferation training, there is an intrinsic challenge in ensuring that trainee knowledge and experiences gained from workshop attendance are translated into improved practice. It is worth mentioning that sustainable outcomes are relevant to both the individual and their organization, and such an approach can help address challenges like high staff turnover which leads to the need for repeated training. In fact, sustainable outcomes can even extend to the national and regional levels due to the process of knowledge diffusion. A pertinent example of the latter is how the Black Sea Women in Nuclear Network (BSWN) was formed by a group of women from Bulgaria, Georgia, Moldova, Romania, Turkiye, and Ukraine in Odessa in 2021, with its first official meeting held in Malta in 2022. The BSWN's work has spread regionally and has even played a role in keeping nuclear and radiological materials safer in Ukraine following Russia's invasion.

A number of steps can be taken to facilitate sustainable outcomes, such as the production of a workshop handbook with session summaries and further reading so that trainees can continue to expand their learning beyond the workshop. A particularly effective way to ensure sustainability is encouraging trainees to run internal training courses in their host institutions: a 'train the trainer' approach. This involves trainees utilizing and expanding on the materials presented in a workshop, including in ways that suit their own organizational contexts.

A study conducted at King's College London in the nuclear security field has charted how such an approach can lead to a shift from an academic 'community of interest' to a 'community of practice'.[47] This involves facilitating a transition from communities where educators 'share little

[47] Matthew Moran and Christopher Hobbs, "From Communities of Interest to Communities of Practice: The Role and Impact of Professional Development in Nuclear Security Education", *British Journal of Educational Studies* 66, no1 (2018), pp. 87-107.

more than a passing awareness' to sustainable communities 'characterized by a shared repertoire of resources, approaches, and frameworks of action.'[48] Thus the aim of such training should be to equip trainees with the appropriate educational resources to foster their own 'communities of practice' on CBRN security which are sustainable but also suited to the specific cultural, national, and organizational context. Indeed, it might even be argued that a successful 'train the trainer' program will eventually become obsolete because the learnings are diffused sufficiently amongst the relevant communities of practice.

Perhaps inevitable with the development of a new curriculum, workshops, and case study sessions may encounter challenges in both design and implementation. As such, a structured post-evaluation process and emphasis on 'lessons learned' can serve to enhance future iterations of the training. Indeed, it is important to create a culture in CBRN nonproliferation training that emphasizes continuous progress and improvement. Evaluation can take the form of both formal and informal feedback. Key questions that should be covered include "Are the principal learning objectives achieved?" and "Are trainees stimulated to think beyond this case and develop insights through linkages across sessions and courses?" This can be investigated by considering the level of engagement and participation, management of the discussion, clarity and balance of the materials, feedback on timing and difficulty, and so forth.[49] It is important for the training organization to maintain a 'lessons learned' document that can inform future instructors as well as case study authors.

Security and organizational culture

Although CBRN safety and security principles are relatively straightforward to outline and articulate, achieving effective security is a complex endeavor. It is also one that varies from country to country as a result of differences in legal and regulatory structures, the threat environment, resource constraints, and political priorities. The importance of achieving a robust security culture in the CBRN context cannot be underestimated given that radioactive sources and chemicals are frequently used either in environments that are 'customer-facing' (such as universities and hospitals) or in industries where radiological sources and chemicals are mobile. As a result, the physical security of settings is often limited for operational or practical reasons. A strong security culture—

[48] Moran and Hobbs, "From Communities of Interest to Communities of Practice", p. 90.
[49] "In-Class Assessment of Discussion-Based Teaching", Christensen Center for Teaching & Learning, Harvard Business School, accessed October 16, 2023, https://www.hbs.edu/teaching/Documents/In-Class-Assessment.pdf.

whether through the development of human resources or employees' individual actions—is essential in ensuring the security of CBRN materials and equipment. The case study approach, by drawing on practical examples has particular resonance here to inculcate the less tangible concept of security culture. For example, case studies that have explored the 'normalization of deviance' concept—such as in the Deepwater Horizon oil spill and Space Shuttle Challenger explosion—can be used to explain how disasters are often the result of human error.[50]

Meanwhile, there is growing recognition that academic and research environments pose particular vulnerabilities in the CBRN dimension.[51] Around the world there are huge numbers of institutions housing hazardous CBRN materials for research purposes, ranging from biological and chemical agents to HASS sources and nuclear research reactors. These institutions face the perennial tension between, on the one hand, implementing CBRN controls to protect the wider community from non-state actors seeking to procure such materials for nefarious purposes, and, on the other, ensuring academic freedoms to facilitate independent and original research. A related risk is the theft of technology and sensitive information from universities and research institutions by non-aligned states seeking to enhance their military capabilities and by proliferator states pursuing WMD programs.[52] A key takeaway for CBRN education and training is that the locus of risk and vulnerability in the CBRN dimension may not be obvious—and trainers need to be cognizant of evolving security trends. CBRN case studies, such as those developed by King's College looking at the academic and research environment, can be valuable as a means of characterizing the multifaceted and nuanced nature of CBRN security issues.[53] Another takeaway is that while the need for protection may seem obvious and irrefutable, in reality those working with CBRN materials on the 'coalface' may in fact be under pressure to

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[50] The 'normalization of deviance' concept was first coined by sociologist Diane Vaughan; see *The Challenger Launch Decision: Risk Technology, Culture and Deviance at NASA,* (Chicago: University of Chicago Press, 1996).

[51] Jinho Chung et al., "Nuclear Security within Academic and Research Organisations: A Handbook of Global Case Studies", CSSS Occasional Paper Series, King's College London, March 25, 2022, https://kclpure.kcl.ac.uk/ws/portalfiles/portal/170404255/NS_in_Academic_and_Research_Organisations.pdf.

[52] Emma Scott, Ross Peel, Felix Ruechardt, and Nick Mitchell, "Catalogue of Case Studies on Intangible Technology Transfers from Universities and Research Institutes", CSSS Occasional Paper Series, King's College London, September 2020, https://www.kcl.ac.uk/csss/assets/itt-case-studies-2020.pdf.

[53] See Scott et al., "Catalogue of Case Studies on Intangible Technology Transfers from Universities and Research Institutes" and Chung et al., "Nuclear Security within Academic and Research Organisations".

balance multiple and competing interests (in the education sector, for instance, protection needs to be offset against academic freedom).

Online and hybrid delivery formats

In the past two decades, online tools such as the IAEA's nuclear security e-learning platform have represented valuable resources for disseminating information to individuals working with CBRN materials around the world.[54] The digitalization of training saw a huge uptick with the Covid-19 pandemic, leading to significant innovation in the delivery methods for CBRN training. However, early on in the pandemic, training was an area of business operations that was often significantly undermined, being regarded as less important given the imperatives of saving lives. As a result, many organizations initially canceled or delayed training.[55] Nevertheless, most such organizations subsequently found ways to transition to alternative modes of delivery, particularly through the development of digital platforms. Since the pandemic, the use of digital platforms has proliferated, with organizations recognizing the beneficial impacts of reaching larger audiences and working across multiple geographies.

Many aspects of CBRN nonproliferation are set to continue being delivered by either digital platforms or hybrid formats (a combination of digital and in-person) in the longer term.[56] Case studies are particularly suited to the digital approach due to their ability to motivate, captivate, and engage. Nevertheless, despite online and hybrid delivery formats facilitating greater inclusion in CBRN training programs, there are still many communities globally that do not have access (or stable access) to the internet, particularly in sub-Saharan Africa.[57] As such, online delivery formats are not necessarily a panacea to the deep structural inequalities that continue to block access to training for some communities. Furthermore, in many cases, online training can never fully replicate in-

[54] The IAEA has developed e-learning courses on a broad range of nuclear security topics (in all official languages), with the objective to develop human resources around the world; see http://elearning.iaea.org.

[55] Sarah Tzinieris, Christopher Hobbs, and George Foster, "Lessons for Nuclear Security from the UK's Response to Covid-19", CSSS Occasional Paper Series, King"s College London, 2022, https://kclpure.kcl.ac.uk/ws/portalfiles/portal/218970353/Lessons_for_Nuclear_Security_from_the_UK_s_Response_to_Covid_19.pdf.

[56] Tzinieris et al., "Lessons for Nuclear Security from the UK's Response to Covid-19".

[57] Charlie Muller and João Paulo de Vasconcelos Aguiar, "What Is the Digital Divide?" Internet Society, 2022, https://www.internetsociety.org/blog/2022/03/what-is-the-digital-divide.

person training, especially in cases where the involvement of physical materials or physical locations is integral to the learning outcomes.

Supplementing the case approach

Tabletop exercise

CBRN nonproliferation programs can make significant use of real-life case studies through a tabletop exercise based on a hypothetical CBRN facility. In a typical tabletop exercise, trainees are organized into groups of between three and six people to work on a hypothetical scenario although this should be realistic and relatable to the trainees. Within their teams, trainees navigate scenarios such as a hypothetical medical facility containing several high-activity radioactive sources, with information provided to trainees on the perceived threat and current security system and practices in place. Trainees working in small groups might be asked to put themselves in the mind of the adversary and consider how successful attacks against the facility could be perpetrated. This is a commonly utilized approach known as 'red teaming' where an assembled group simulates an attack on the target organization.[58]

In this context, trainees can be asked to construct realistic attack pathways as a means of highlighting the weaknesses within the facility security system. The task might then evolve into an assessment of cost-effective security solutions. At all times, trainees should be encouraged to consider an intelligent adversary that represents a dynamic and ever-changing threat—requiring an approach capable of being modified in response to changes in security.[59] One of the benefits of tabletop exercises is that they can be used for testing action plans and operational procedures at specific facilities. In the nuclear security field, training frequently makes use of a hypothetical nuclear facility called Shapash, developed by the IAEA.[60] The UN Interregional Crime and Justice Research Institute (UNICRI) is an example of an organization that utilizes tabletop exercises to full effect, with an emphasis on deploying a practical approach in its security training.[61]

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[58] For a full discussion of 'red teaming' see BSI Group, 2023, "What is red teaming and what are the benefits to my business", https://www.bsigroup.com/en-GB/blog/Digital-trust-blog/what-is-red-teaming.

[59] M. Kenney, "From Pablo to Osama: Counter-Terrorism Lessons from the War on Drugs", *Survival* 45 (2003), pp. 187-206.

[60] "Step into the World of Nuclear Security Training – Online, Mobile and in 3-D", News, IAEA, 2017, https://www.iaea.org/newscenter/news/step-into-the-world-of-nuclear-security-training-online-mobile-and-in-3-d.

[61] "Training and Advanced Education", UNICRI, 2024, https://unicri.it/services/education_training/postgraduate.

Through-course project

A through-course project (TCP) is similar to a tabletop exercise, but here the activity is conducted over several sessions (usually over several days). Each task that is set builds on the previous one and new information is revealed at each stage. The advantage of this is twofold: i) the trainees accumulate knowledge as they go along, so they are not overwhelmed with information and can remain focused; ii) each new task mirrors the curriculum from the training session delivered previously, thereby cementing the learning session-by-session or day-by-day. A TCP might culminate in a special session at the end, such as group presentations in front of the wider classroom with instructors also taking part (e.g., they might play the role of a governing board or regulator).

The simulation format—utilized in case study sessions, tabletop exercises, and TCPs—enables the trainees to engage with the subject matter in a more focused way than might be the case with traditional teaching formats such as lectures. In particular, the simulation format 'brings to life' the complexities of real-world problems and encourages new thinking and creativity on finding solutions to CBRN problems. This is especially useful for helping trainees to engage with the more intangible topic of security culture. Indeed, the simulation format is particularly relevant to CBRN materials where security rests far less with 'guns, guards, and gates' than the personnel responsible for their protection.

Polling and questionnaires

Employing polling and questionnaires during training is another way to maximize the interactive learning format. Electronic voting systems allow instructors to pose questions during a training session, enabling trainees to express their views on issues of importance. Trainees click on handheld devices, centrally connected to the instructor. The speaker waits until all responses are collected (usually no more than a few minutes), then pulls them into a graph displayed automatically in their presentation slide pack. The results can be used to generate a classroom discussion to probe the answers.

In addition to the fruitful classroom discussion, this format provides instructors with real-time information on participant understanding so any areas of confusion can be clarified. Another benefit is trainees have the freedom to participate anonymously; but equally those who feel comfortable in sharing their views publicly can do so during the follow-up discussion. Since the Covid-19 pandemic, there are a number of companies now offering polling and questionnaire formats on mobile phone apps.

Site visit

A site visit can be an extremely valuable aspect of a training course as it goes to the heart of experiential learning. In the CBRN context, it might involve a trip to a facility where some of the education from the course can be seen from the industry and practitioner perspective. Importantly, this experience taps into the memory aspect that is essential for deep learning. Case studies can even be used in tandem with the site visit to maximize learning opportunities here. For instance, a visit to a biological laboratory could be supplemented by the dual-use case studies made available by the Federation of American Scientists on its Biological Research platform.[62] However, disadvantages of site visits include the cost, resources, and time involved. Still, it is sometimes possible to make use of local visits that, while more limited, can still bring a lot of value to trainees.

Limitations of the case approach in CBRN training

Despite the many advantages conferred by case studies, the approach inevitably has its limitations and is still mostly used in conjunction with more traditional pedagogical formats such as lectures. While case studies are highly valuable teaching methods, they do not fully replace the necessary provision of onsite training. The nature of many CBRN materials is that they sometimes can be somewhat inaccessible; for instance, in the case of radiological sources, there are patient confidentiality issues in hospitals and it is difficult logistically to visit oil and gas drilling rigs. As such, the development of alternative learning tools for workshops—particularly the simulation format—takes on even greater relevance. Here follows a discussion of the limitations of case studies, but also actions that can be taken to mitigate these.

Challenges in teaching case studies

Most obviously, case studies place pressure on instructors who often need to spend a considerable amount of time planning and developing the materials. Even with appropriate preparation, 'the outcome of the exercise is not necessarily fixed'.[63] Instructors may be faced with not only unexpected questions but also with students making unanticipated decisions about a particular case. Ensuring that the case study remains aligned with the objectives of the broader learning goals remains a

[62] See Federation of American Scientists, "Case Studies in Dual Use Biological Research", accessed October 16, 2023, https://biosecurity.fas.org/education/dualuse/index.html.
[63] Chapman et al., "Security Culture".

constant challenge.[64] It is worth noting that with the growing global interest in the use of case studies in teaching, a market has now developed in this area, which, as mentioned, remains dominated by American-authored cases[65]— although the landscape is starting to shift.

Ultimately, the strength of the case study approach comes down to the quality of the teaching, requiring skillful facilitators who can cultivate a dynamic and engaging discussion. To be effective, the activity requires not only a relevant, topical, and nuanced case study, but also a skillful facilitator who can guide cultivate a dynamic and engaging group discussion. Case studies remain popular with students, with evidence showing that instructors employing this format rank consistently highly on satisfaction surveys.[66] Yet, it is important to note that the engagement of students or trainees is in part related to the enthusiasm with which instructors embrace case studies as a pedagogical tool.

Instructors are also required to take on the role of facilitator in running a case study exercise, thereby losing their status as the provider of answers.[67] This unfamiliar dynamic can help invigorate a classroom setting, but it can also unnerve students.[68] For this reason, there is a risk that instructors can, albeit unintentionally, guide trainees to solutions that 'confirm the validity of concepts being taught' rather than employing case studies to generate an open-ended discussion.[69] It is therefore recommended that instructors accept a degree of flexibility in the classroom, at the same time as being prepared to manage potential dissent.

Case method teaching has been described as 'the art of managing uncertainty—a process in which the instructor serves as a planner, host, moderator, devil's advocate, fellow student, and judge.'[70] That is a lot of skills for an instructor to possess or learn. It requires a good understanding of participant-centered learning, leadership presence, interpersonal skills, and where possible some form of teacher training.[71] On top of this, the learning environment has to be given careful

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[64] Hobbs and Moran, "Insider Threats".

[65] As mentioned, Harvard Business School earned US$16.7 million from selling case studies in 2022; see 2022 Annual Report, p. 24.

[66] Leonard and Cook, "Teaching with Cases", p. 96.

[67] S.W. Henson, P.A. Kennett, and K.N. Kennedy, "Web-based cases in strategic marketing", *Journal of Marketing Education,* Vol 25, Issue 3 (2003), pp. 250-259.

[68] Chapman et al., "Security Culture".

[69] Larry E. Greiner, Arvind Bhambri and Thomas G. Cummings, "Searching for a Strategy to Teach Strategy", Academy of Management, *Learning and Education* 2, n 4 (2017).

[70] "Teaching by the Case Method", Christensen Center for Teaching & Learning.

[71] Joseph Lowman, *Mastering the Techniques of Teaching* (San Francisco: Jossey-Bass Publishers, 1984).

consideration. In various cultures, it is not deemed appropriate to question materials or instructors, and some trainees may be unfamiliar with case studies and case method learning. If these challenges are not taken into account and addressed, then the impact of the case study will be diminished.

Diversity issues

Another limitation of the case study approach is that scenarios are still too often based on large-scale, corporate organizations in the West. For too long case studies have tended to reflect Western priorities and may not be easily relatable to non-Western audiences. For many students and trainees, the case studies they are provided are simply not relevant to their own experiences or future career aspirations.[72] Women leaders, for example, are still insufficiently represented in case studies, while the value of other perspectives, such as those of labor unions, may be underestimated.[73] For this reason, higher education institutions in other parts of the world are increasingly developing their own case studies—with the aim of making these more relevant and practical to their students.[74]

Another drawback is case studies may not fully reflect real-world situations, as these tend to evolve with information coming to light over a period of time. Case studies, by contrast, usually pre-assemble all the essential facts[75]—enabling students to evaluate a far wider range of options and pathways at any one time. One way to mitigate this particular issue is preparing case study materials that depict an evolving narrative, with new information provided at several points during the activity. As such, instructors should think carefully about the set of case studies they will utilize in their training.

A case study challenge unique to the CBRN arena is the fact that many incidents simply will never be publicly shared. No government or facility likes to admit to its mistakes. Crucially, many *cannot* admit to mistakes, because it could pose a security risk. For instance, explaining that a fence

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[72] Howard Forman, "Participative Case Studies: Integrating Case Writing and a Traditional Case Study Approach in a Marketing Context", *Journal of Marketing Education* 28, (2006,), pp. 106-113.
[73] Andrew Jack, "Why Harvard's case studies are under fire", *Financial Times*, October 29, 2018, https://www.ft.com/content/0b1aeb22-d765-11e8-a854-33d6f82e62f8.
[74] Jack, "Why Harvard's case studies are under fire".
[75] Ellen J. Kennedy, Leigh Lawton, and Erika Walker, "The Case for Using Live Cases: Shifting the Paradigm in Marketing Education", *Journal of Marketing Education* 23, no 2 (2001), pp. 145-151.

could not be repaired due to insufficient funds could lead adversaries to monitor that area for further vulnerabilities. One way to mitigate this issue is to develop case studies that focus on good practices. For example, there is a case of a South African organization that was able to capitalize on grassroots initiatives to strengthen nuclear as well as chemical security.[76] In fact a number of organizations have produced good practice materials[77]—while scholars like Matthew Bunn and Scott Sagan have focused on 'worst practices' in order to emphasize the importance of actually *learning* from lessons learned.[78] Likewise tabletop exercises can be utilized to focus on good practices.

Resourcing constraints

A broader challenge for training in the area of CBRN nonproliferation is to ensure that sufficient resources are devoted to the endeavor. In recent years, education and training specifically in the area of CBRN nonproliferation have been recognized by the IAEA, the OPCW, and national governments alike as vitally important in view of the vast numbers of incidents of CBRN proliferation that has taken place historically, especially in the context of often lax and uneven regulatory frameworks. While many national governments have been increasing resources in this area, one of the perennial challenges is that funding cannot keep pace with growing global demand.

A related issue is that much of the funding available for CBRN nonproliferation training tends to support activities related to nuclear materials (often civil nuclear sites), based on the belief that these represent a more attractive target than other CBRN materials for a potential adversary. Faced with scarce resources, ensuring that training for other aspects of the CBRN nexus induces sustainable outcomes in trainees' home countries is a priority and requires support from governments, corporations, and other key stakeholders around the world. However, this raises another question on how to measure these

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[76] Jinho Chung et al., "Nuclear Security within Academic and Research Organisations: A Handbook of Global Case Studies", CSSS Occasional Paper Series, King's College London, 2022, https://kclpure.kcl.ac.uk/portal/files/170404255/NS_in_Academic_and_Research_Organisations.pdf.

[77] See for instance the publication of European Nuclear Security Regulators Association (ENSRA), "A Compendium of good practices for the inspection of security of nuclear materials and facilities", 2021, https://www.ensra.org/wp-content/uploads/2021/08/ENSRA-REPORT-2021-compendium-good-practices-nuclear-security-inspections.pdf.

[78] Matthew Bunn and Scott D. Sagan, *A Worst Practices Guide to Insider Threats: Lessons from Past Mistakes* (Cambridge, MA: American Academy of Arts and Scientists, 2014).

sustainable outcomes. Whilst feedback collected during workshops is often resoundingly positive, it is more difficult to assess the tangible impacts of the workshops over the longer term.[79]

This all suggests that the private sector will need to play a larger role in CBRN training. While this area is 'arguably still viewed by many within the industry as rules and regulations to be followed, and often as a burden, rather than as a key organizational goal', scholars have drawn attention to how security might be reframed as a 'business enabler' through changing organizational beliefs and attitudes.[80] CBRN weaknesses can have long-term cost implications—not only financial, environmental, and legal, but also reputational and societal—and articulating the value of security is a society-wide imperative, not only the responsibility of states and operators. Another benefit of having the private sector involved in CBRN nonproliferation training is that it can also bring to bear its experience in risk mitigation.

Growing threat from mis- and dis-information

A discussion of the limitations of the case studies approach would not be complete without acknowledging that not all materials relevant to CBRN training are valid or, indeed, grounded in fact; this includes case studies that instructors might find from an online search. This is particularly true in a time of mis- and dis-information, with campaigns and spurious information peddled by various non-state and state actors for political or financial gain and amplified across social media. For example, there is evidence that in the context of the Russian invasion of Ukraine, the Russian government has waged a biological weapons disinformation campaign accusing the Ukrainian authorities of secretly working with pathogens of dangerous infections, with American support.[81] Such mis- and dis-information campaigns are likely to target organizations and states deemed most vulnerable. Instructors can seek to mitigate this risk by, firstly, ensuring that the selected training materials derive from legitimate sources (for instance the IAEA in the case of nuclear security training), and, secondly, that trainees are made aware of such risks and are equipped with the skills necessary to identify legitimate information and conduct fact-checks.

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[79] The statement that feedback collected during workshops is often resoundingly positive is based on the authors' experience of developing such workshops.

[80] Karl Dewey et al., "Reconceptualising Nuclear Security as a Business Enabler", paper presented at the IAEA International Conference on Nuclear Security, 1, 2020, https://kclpure.kcl.ac.uk/ws/portalfiles/portal/170357050/IAEA_CN_278.pdf.

[81] "Ukraine war: Fact-checking Russia's biological weapons claims", *BBC*, March 15, 2022, https://www.bbc.co.uk/news/60711705.

Conclusion

Despite ongoing efforts to strengthen the nonproliferation of CBRN materials and equipment, a number of challenges remain at the local level. While the case of Sister Megan is unique and unlikely to repeat itself, the threat of a combination of small human security culture failures remains ever present at facilities across the world. The development of training that utilizes case studies is just one activity within global endeavors, aimed at strengthening security within a diverse range of operating environments. As evidenced by academic studies, the learning-centered approach with a focus on active participant engagement is most effective in fostering deep learning. Other forms of interactive teaching methods—including group discussions, tabletop exercises, and electronic voting—also help disseminate key concepts and support the sharing of international best practices.

There remains much work to be done to support training in the area of CBRN nonproliferation. This involves more concerted efforts by national governments, corporations, and other key stakeholders to promote wider CBRN security—not only nuclear security—as well as provide the associated funding. Organizations such as universities, professional societies, and online networks constitute instrumental actors in these endeavors—directing bottom-up pressures on governments and agencies, as well as diffusing information and educational resources within their circles of influence. There are already signs that informal communities of interest in the CBRN field are evolving into more structured communities of practice.

In view of the limited funding available, the objective should be to ensure sustainable outcomes through using low-cost resources such as case studies, as well as equipping practitioners with sufficient resources to disseminate their own education and training activities at their home organization. Overall, the benefits of the case study approach outweigh the challenges and limitations, though they are likely to remain part of a broader set of varied teaching formats. Meanwhile, the speed of technological innovation means that a number of skilled and technical roles will be gradually replaced by machines in the coming decades. The development of ‘soft skills’ such as critical thinking, problem-solving, and interpersonal abilities will be increasingly valued in the employees of the future.

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Training to embrace uncertainties? The 'Pathway Evolution Process' serious game for assessing toxic waste program

Céline Parotte,[*] *Nathan Flore,*[**] *Sacha Frenay* [***]

Abstract

This paper aims to evaluate the 'Pathway Evolution Process' (PEP) serious game method, developed by nuclear regulators and their technical support at the European level (SITEX network). This method aims to organize the exchange of experience and (non-)knowledge between nuclear waste experts, stakeholders, and the public on the safety and management of the long-term radioactive waste program, by placing uncertainty at the center of the evaluation process. Such interdisciplinary dialogue also promotes learning for both players and experts. This paper draws on feedback from its implementation in Belgium in 2021 with engineering and policy researchers, students, and representatives of Belgian Nuclear Regulatory Bodies. Considering this method as a hybrid forum, the paper highlights how the 'game' side allows participants to systematically evaluate and question all the ethical and socio-technical aspects of the program while leaving space for contrasting positions to emerge. It also emphasizes that experts

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can play different roles when interacting with different audiences. More generally, this article questions the value and limits of serious games for knowledge production on sensitive and complex policies.

Keywords

Pathway Evolution Process serious game, safety and vulnerability assessment, Belgian experiment, toxic waste, public participation, expert participation, hybrid forum, lessons-learned game.

Introduction

Radioactive waste is one of the most undesirable and sensitive materials to manage and control in both the short and long term. To this end, the role of nuclear experts remains key, but since the 1950s they have faced a series of well-documented challenges. These challenges include (but are not limited to) the death and lack of succession among nuclear waste experts,[1] the disinterest of (future) stakeholders,[2] strong opposition to site selection,[3] refusal of public participation,[4] and, in some countries, a gap between an advanced research program on radioactive waste management (RWM) and public policies that lag behind in this area.[5]

Slowly and in the wake of strong protests, experts measured that managing this toxic waste is not only a technical issue but also a *socio-technical* one that differs from one national RWM context to another.[6] Nuclear waste experts must address several challenges simultaneously, including how to maintain knowledge, how to raise awareness of the process among all stakeholders, and how to design the long-term assessment of the safety aspects of a public policy. This involves considerations such as how to monitor, what questions to ask, what criteria to adopt, and with whose support.

Several researchers have already shown that nuclear waste experts are under pressure, underlining that they are often caught in the crossfire of the multidimensionality of the toxic object they manage or control. They are "between the 'participatory turn' that almost forces them to open up to wider interaction, and their responsibility to produce technically sound reports likely to inform decision-makers. (...) They have to deal with the

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[1] E.g., Vincent Ialenti, "Death and Succession among Finland's Nuclear Waste Experts", *Physics Today,* Vol. 70, N°10 (October 2017), pp. 48-53.

[2] E.g., Céline Parotte, Catherine Fallon, "The future for long-term management of high-level radioactive wastes and spent fuel in Belgium. Synthesis of the Delphi inquiry", Spiral research Centre, January 30, 2020.

[3] Achim Brunnengräber, et al., eds., *Nuclear Waste Governance. An International Comparison*. Springer VS, 2015.

[4] Brian Wynne, "Public participation in science and technology: performing and obscuring a political–conceptual category mistake", *East Asian Science, Technology and Society: An International Journal*, Vol.1, N°1 (October 2007), pp. 99–110.

[5] Jantine Schröder, Anne Bergmans, and Erik Laes, "Advanced research, lagging policy: nuclear waste governance in Belgium", in *Nuclear Waste Governance,* eds. A. Brunnengräber et al., (Springer VS, 2015) pp. 141–155.

[6] Brunnengräber et al., *Nuclear Waste Governance. An International Comparison*.

double imperative of ensuring social and technical robustness."[7] In practice, the 'socio-technical divide' remains.

In that view, the European Sustainable Network for Independent Technical Expertise for Radioactive Waste Disposal (SITEX), composed of national nuclear regulators and their technical support,[8] with the assistance of Mutadis (a company specializing in public engagement), started designing a serious game in 2015 to innovate and strengthen interactions between nuclear regulatory bodies and civil society. It was intended as an exercise in participatory and comparative assessment of alternative scenarios for the long-term management of radioactive waste, in which civil society has a role to play. The safety authorities were convinced of the need for experts to interact with the various stakeholders as "it is now recognized by regulators that openness and transparency significantly contribute to the continuous improvement of nuclear safety."[9]

Serious games (SGs) involve the application of game elements in non-game contexts. They differ from other games in that they are explicitly designed to develop a specific aspect of knowledge or training rather than simply providing entertainment, thus reconciling two *a priori* paradoxical imperatives.[10] On the one hand, the 'serious' side aims primarily at establishing an educational value: by simulating real-world situations, it encourages players to engage in complex processes.[11] SGs allow players to face the challenges of a given issue and to experience the realistic impact of their decisions, thus influencing the behavior of stakeholders in

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[7] Céline Parotte, Pierre Delvenne, "Taming uncertainty: towards a new governance approach for nuclear waste management in Belgium", *Technology Analysis & Strategic Management* (2015), p. 9.

[8] The purpose of SITEX is to "enhance and foster cooperation at the international level in order to achieve a high quality Expertise Function in the field of safety of radioactive waste management, independent from organizations responsible for the implementation of waste management programs and waste producers, aiming at supporting the Nuclear Regulatory Authorities, as well as the Civil Society". SITEX Network, "Home", accessed March 4, 2024. https://www.sitex.network

[9] Valéry Detilleux, Frank Lemy, Frédéric Bernier, Marina Surkova. "The PEP serious game to explore the complexity of a safe long-term radioactive waste management: a first experience in Belgium", *Eurosafe*, Vol. 5 (2021), p. 1.

[10] Marios Stanitsas, Konstantinos Kirytopoulos, Elise Vareilles, "Facilitating sustainability transition through serious games: a systematic literature review", *Journal of Cleaner Production*, Vol.208 (2019), pp. 924-936.

[11] Marcel Fernandes Dallaqua, Breno Nunes, Marly M. Carvalho, "Serious games research streams for social change: critical review and framing", *British Journal of Educational Technology*, Vol. 55, N°2 (2023), pp. 460-483.

non-game situations.[12] On the other hand, the 'game' side increases engagement and intrinsic motivation, frees players from the pressure of tangible consequences, and allows them to explore all possible futures.[13] In doing so, SGs can enhance the acquisition of cognitive knowledge and skills such as problem-solving, decision-making, and situational awareness,[14] and can prove to be a useful data collection method, including for emergency management,[15] to raise awareness of hazardous pollution,[16] and to collectively explore potential transition processes.[17]

While there are many types of SGs, the one under investigation in this article is a board game called 'Pathway Evolution Process' (PEP) serious game. Its creators define it as "an interactive dialogue tool (...) conceived as an exercise in the form of a serious game, allowing the participative and comparative evaluation of different scenarios for the long-term management of radioactive waste."[18] In 2016, the beta version was first tested by 32 participants at the European level.[19] Since its creation, the game has been tested in several formats (including online) and in several national contexts, including in France (2019), Czech Republic (2017), Switzerland (2021), and Belgium (from 2021 to 2024).

This paper focuses on the Belgian experiments, specifically the first one in 2021. It aims to evaluate this application and to analyze how and why the PEP SG may facilitate learning and interdisciplinary thinking on a complex and sensitive program, as well as the added value and limitations it bears for RWM knowledge production.

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[12] Mario Silic, Paul Benjamin Lowry, "Using design-science based gamification to improve organizational security training and compliance", *Journal of management information systems*, Vol.*37*, N°1 (2020), pp. 129-161.

[13] Gilles Brougère, "Le jeu peut-il être sérieux ? Revisiter Jouer/Apprendre en temps de serious game", *Australian Journal of French Studies,* Vol.49, N°2 (2012), pp. 118–129.

[14] Pieter Wouters, Erik van der Spek, Herre van Oostendorp, "Current Practices in Serious Game Research: A Review from a Learning Outcomes Perspective", in *Games-Based Learning Advancements for Multi-Sensory Human Computer Interfaces: Techniques and Effective Practices*, eds. T. Connoly et al., (Hershey, PA : GI Publishing, 2009), pp. 232–251.

[15] Olivier Borraz, et al., « Peut-on apprendre à décider en jouant ? », *Entreprises et histoire*, Vol.97 (2019), pp. 110-129.

[16] Curt D. Gervich, et al., "Toxic Release! The role of educational games in teaching and learning about hazardous pollution", *Journal of Environmental Studies and Sciences*, Vol.6, N°3 (2016), pp. 589-596.

[17] Stanitsas, Kirytopoulos, Vareilles, "Facilitating sustainability transition through serious games: A systematic literature review".

[18] SITEX Network, "News & Events", accessed December 14, 2023, https://www.sitex.network/events-and-news/.

[19] REC, FANC, Mutadis, "Workshop with civil society". Minutes, Budapest: Hungary, June 2016.

To address these questions, this paper is divided into three sections. The first section elaborates on the theoretical concept of the 'hybrid forum'[20]—which we mobilize to assess whether the PEP SG can be considered as a new space for discussion that favors the encounter between experts and the public—then briefly describes the rules, objectives, and target groups of the PEP SG, as well as the different training sessions and experiments. The second section focuses on the different lessons learned by the non-experts, the nuclear waste experts, as well as the facilitators, and assesses the role of the experts in the debate. The third section discusses the opportunities and the limits of the PEP SG for RWM knowledge production, emphasizing the implications of genuinely addressing the uncertainties inherent to RWM. Finally, we conclude and highlight three main elements from the Belgian session that should be explored in more depth for future PEP SGs.

Theory, methods, and data collection

Theoretical assumptions: assessing the PEP serious game as a hybrid forum

Theoretically, we abductively analyze the PEP SG as a form of hybrid forum method.[21] A 'hybrid forum' is understood as a public space that brings together a variety of heterogeneous voices in the deliberation—such as experts, affected or concerned citizens, political leaders, or civil society organizations. This creates "emergent concerned groups" with "multiple alliances among the various components of these groups."[22]

Such a space of discussion aims to feed the decision-making process on controversial subjects. The technique has already been tested in many countries and contexts, including in the case of RWM in France[23] and

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[20] Michel Callon, Pierre Lascoumes, Yannick Barthe, eds., "In the Search of a Common World", in *Acting in an Uncertain World: An Essay on Technical Democracy*, pp. 107-152. Cambridge: MIT Press, 2009.

[21] Michel Callon, Pierre Lascoumes, Yannick Barthe, *Agir dans un monde incertain. Essai sur la démocratie technique*, (Seuil, 2009), pp. 1-368.

[22] Silvia Macchi, "Contexts of interaction for plural city politics: hybrid forums and cosmopolitics", *Plurimondi,* Vol.5 (2001), p. 9.

[23] Callon, Lascoumes, Barthe, *Agir dans un monde incertain*; Marie Kerveillant, Michael Mangeon, Francois Jeffroy, Olivier Saulpic, "Opening to the public: hybrid forum of reproduction of a technical dialogue between experts? Study of public opening device: the Cigeo Project Security Options File.", Social Sciences and Humanities - HSS, Boulogne-Billancourt: France, December 2019.

Denmark[24], in the case of energy production sites,[25] to compare radiation standards,[26] to ensure sustained collaborations after environmental disasters,[27] or to question the uncertainties of resource extraction.[28] Applied to sensitive policies, a hybrid forum can provide strategic conversations to enable an "open, explicit, shared and flexible sense of future to be developed through a process of interactive and immersive learning that takes place in imagined future situations."[29] The method of hybrid forum suggests transforming sociotechnical controversies produced by experts, non-experts, citizens, and politicians into productive conversations.[30]

Translated into organized activities such as the PEP SG sessions, the hybrid forum aims to promote the co-production of knowledge (and lack of knowledge) between laypeople, experts, and non-human actors (e.g. radioactive waste), without excluding any actor *a priori*.[31] Specifically, it focuses on three different dimensions that we will analyze below: 1) the context of uncertainties; 2) the learning of the actors involved and how their identities are redefined during the meetings; and finally, 3) the diversity of issues to be addressed in the search for a common good.

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[24] Rosa Nan Leunbach, Kristian H. Nielsen, "Exploring the Dialogical Space of Hybrid Forums: The "Predictably Unpredictable" Case of Radioactive Waste Management in Denmark, 2003-2018", *Bulletin of Science, Technology and Society*, Vol. 39, N°1-2 (2019), p. 5.

[25] Nichole Dusyk, "The transformative potential of participatory politics: Energy planning and emergent sustainability in British Columbia, Canada", Doctoral Thesis, University of Bristish Columbia, 2013.

[26] Aya Hirata Kimura, "Standards as Hybrid Forum: Comparison of the Post-Fukushima Radiation Standards by a Consumer Cooperative, the Private Sector, and the Japanese Government", *The International Journal of Sociology of Agriculture and Food*, Vol. 20, N°1 (2013), pp. 11–29.

[27] Ignacio Farias, "Devising hybrid forums. Technical democracy in a dangerous world", *City. Analysis of Urban Change, Theory, Action*, Vol.20, N°4 (2016), pp. 549-62.

[28] Aleksandra Lis, Agata Kinga Stasik, "Hybrid forums, knowledge deficits and the multiple uncertainties of resource extraction: Negotiating the local governance of shale gas in Poland", *Energy Research & Social Science*, Vol.28 (2017), pp. 29-36.

[29] Angela Wilkinson, "Using strategic foresight methods to anticipate and prepare for the jobs-scarce economy", *European Journal of Futures Research*, Vol.4, N°12 (2016), p. 5 (pp. 1-11).

[30] Callon, Lascoumes, Barthe, *Agir dans un monde incertain.*

[31] Emma Cardwell, Claire Waterton, "How to move beyond the dialogism of the 'Parliament of Things' and the 'Hybrid Forum' when rethinking participatory experiments with ANT", in *The Routledge Companion to Actor-Network Theory*, edit. A. Blok, I. Farias, and C. Roberts, C., (Routledge, 2019), pp. 378-388.

First, hybrid forums emerge or are mobilized in controversial and uncertain contexts.[32] Such spaces typically involve unanticipated events and often confrontations, where different perspectives clash and alternative knowledge claims and policy recommendations are made.[33] In the PEP SG, for example, we will see that the design and its applications have been framed to make unexpected events and uncertainties the basis for reflection.

Second, the hybrid forum promotes learning among the actors involved. It organizes interactions for mutual learning to take place, even when there are strong debates and oppositions, taking into account power inequalities that arise in participatory exercises. Lay people gain knowledge but also skills by working with experts, who in turn benefit from the new framings and insights of the former. Moreover, participants must take action, despite the uncertainties. We will see that the PEP SG challenges players to constantly move forward, effectively forcing them to decide.

Third, the issues addressed in a hybrid forum are extremely diverse: they are not exclusively technical, but also philosophical and political. Heterogeneous groups of actors may find common interests or issues. Others may be modified by exposure to the suggestions of new groups. Encouraging diversity and openness in discussions is one of the purposes of the PEP SG, while discussions on different issues and challenges can in turn change the way in which a program is perceived and implemented.

PEP serious game application in Belgium

In Belgium, PEP SG was first applied at the University of Liège in collaboration with the Faculty of Applied Sciences and the Faculty of Law, Political Science and Criminology, and with the support of the national regulatory authorities (the Federal Agency for Nuclear Control—FANC[34]—and its technical support organization, Bel V[35]). This first experiment gathered eighty-eight participants-gamers from engineering and political science studies. A dozen academics—engineers and political scientists—were present to ensure facilitation: each group was supervised by two

[32] Virginie Amilien, Barbara Tocco, Paal Strandbakken, "At the heart of controversies: Hybrid forums as an experimental multi-actor tool to enhance sustainable practices in localized agro-food systems", *British Food Journal*, Vol.121, N°12 (2019), pp. 3151-3167.
[33] Leunbach, Nielsen, "Exploring the Dialogical Space of Hybrid Forums", 2019.
[34] For further information, see the official webpage, accessed on December 15, 2023: https://www.belgium.be/en/contactinfo_en_sites/Urls/http_www_fanc_fgov_be.
[35] For further information, see the official webpage, accessed on December 15, 2023: https://www.belv.be/en/

facilitators, wherever possible with a parity between academic interests to allow for multidisciplinary facilitation. Five representatives from the nuclear regulatory body were tasked with introducing the project and circulating among the different groups during the game sessions to answer socio-technical questions as nuclear waste experts.

This article focuses on the primary data and lessons learned collected during the first edition in April 2021,[36] i.e. the collective written and oral feedback from non-experts and nuclear waste experts at the end of the game sessions, the analysis of the full transcripts of the sixteen PEP SG sessions (each lasting three hours), as well as the written and oral reports of the authors.[37]

In the Belgian version, the PEP SG was organized in four phases, including two short expert presentations, the game session, and collective feedback. During the first short presentation, the nuclear waste experts from nuclear regulatory bodies highlighted the key elements of the Belgian nuclear context, explained what 'radioactivity' means, described the different types of radioactive waste, and exposed the short – and long-term solutions currently under consideration. During the second presentation, they explained the board and cards (Figure 1; Figure 2; Figure 3), the objectives of the PEP SG, and the rules.

Since its birth and early developments, the PEP SG method has stabilized three scenarios (materialized by three game boards) that allow players to debate different strategies and socio-technical preferences enabling an evolution from the current situation of RWM to a final safe situation in the long term. Therefore, the core objective is invariably to reach a *safe terminus*— i.e., the protection of people and the environment as the main objective—while recognizing that this objective can be achieved through different *pathways*.

The first game session was automatically played on the 'closed' game board (Figure 1), imposing that efforts and resources are allocated to a swift implementation of geological disposal. After a short break, a second

[36] Nevertheless, since the first edition, numerous PEP serious game sessions have been conducted in Belgium with different target groups (notably with 13 volunteer citizens in November 2022 and with 10-20 representatives of the regional and federal administration in January, March, November 2023 and March 2024). This accumulated experience has contributed to the authors' analytical reflections and has confirmed many of the empirical elements already identified in this paper.

[37] This paper builds on and extends some of the authors previous reflections on this topic published in French in 2021-2022. Céline Parotte, Nathan Flore, "Expérimenter le Pathway Evolution Process (PEP) Serious Game à l'ULiège. Évaluation de la méthode prospective", Spiral Research Centre, December 12, 2022.

game board was chosen, either the open board[38]—an approach that does not choose from the start a specific technical option as a *safe terminus*—or the oriented board[39]—a step-by-step investigation of geological disposal, with the potential for other options as alternatives.

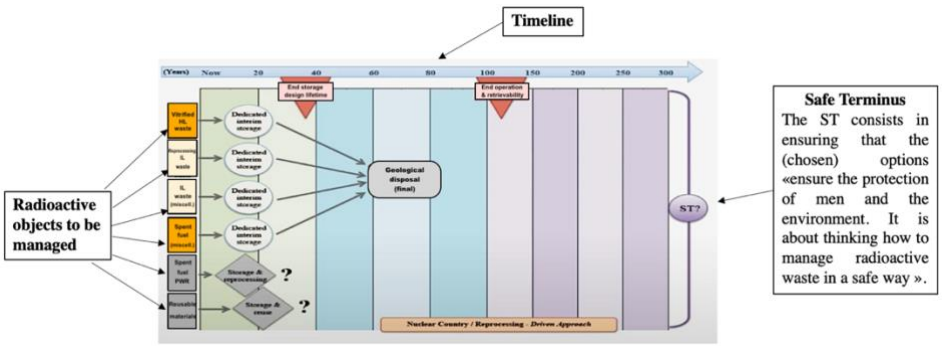

Figure 1 'Closed' game board: driven approach towards geological disposal ©Sitex.

Concretely, the PEP SG has two main effects. First, it confronts the participants, in the more or less long term, with unforeseen and disruptive elements that undermine a particular pathway imposed on them (in this case, one or more RWM options in Belgium). Second, it encourages them to reflect on the sustainability of the pathway based on various indicators: evaluation criteria, risk management, risk transfer, quality of governance, and ethics and values.

Finally, methodological precisions must be made concerning the authors' committed posture and their different roles in data production. In line with pragmatic sociology, we adopted an attitude of engaged researchers: we assume that we are both 'researchers and actors', engaged and involved in various ways—participant-observers, observer-participants, facilitators, player-participants, method evaluators—that affect our object of study. This enrollment was a powerful tool to better understand and adapt the rules and objectives of the game.

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[38] The open approach is based on the implementation of one or more dedicated *robust surface storage* sites, which are planned to last long enough to allow for the development and implementation of a *safe terminus* option that is not yet defined. Rules retrieved in: REC, FANC, Mutadis, "Workshop with civil society". Minutes, Budapest: Hungary, June 2016.

[39] The oriented approach steps from the current *interim storage* to a geological facility which is at first developed as a *geological interim storage*. After some time, the retrievability is given up and either the same site or another one is used as geological disposal, which becomes the *safe terminus*. Rules retrieved in: REC, FANC, Mutadis, "Workshop with civil society".

Below, we will examine the different lessons learned from the facilitator team, nuclear waste experts, and non-experts.[40] Following the iterative process through which the Belgian implementation of the PEP SG was constructed as an analytical guide, the next sections assess (1) how the PEP SG design accentuates the uncertainties, (2) and (3) the questions and issues raised during the game sessions, and (4) the various forms of experts' interventions and their implications.

Lessons learned from facilitators and nuclear waste experts: accentuate uncertainty

The first lessons learned came from the two training sessions organized in April 2021 to prepare the researchers' teams (including PhD students, researchers, and professors) to facilitate the game sessions with interdisciplinary students and nuclear waste experts. These 'test phases' allowed the researchers to evaluate both the rules and the design of the game and led to the implementation of some modifications, highlighting the performative effects of 'learning by doing'.

To meet the initial objectives (to think about safety in times of uncertainty), the facilitation team made four choices which, in practice, tended to accentuate the uncertainties: keeping the complexity, imposing the draw, choosing the strongest initial constraints, and limiting the experts' interventions.

Keeping it complex with simple(r) terms

The first modification addressed the initial complexity of the PEP SG: the titles and descriptions of the cards (namely: 'safe terminus', 'test conditions', 'evaluation criteria') and their articulation in the game were difficult for the facilitator-players to understand. To help future players (in this case, students) better grasp those notions, a translation work was carried out. Initially defined as "a situation in which the safety of all considered categories of waste do not anymore entail an active human contribution,"[41] the *safe terminus* was finally conceptualized and presented as a 'single rule to be respected at all costs: the protection of man and the environment'. Although geological disposal tends to be favored by the scientific community, the notion of *safe terminus* was subject to different interpretations and discussions by the facilitator-

[40] Organising the results based on people's role in the PEP serious game emphasises that this method fosters an eminently collective learning.

[41] REC, FANC, Mutadis, "Workshop with civil society", p. 15.

players. Therefore, it was decided not to introduce the element of 'passive safety' in the definition of the notion. For their part, the cards entitled 'test conditions' were presented as 'disruptive changes, unforeseen events that impose themselves on the players and with which they must contend'.

However, the complexity of both the content and the wording of the cards was almost systematically emphasized by the participants during the game sessions. Yet, instead of hindering discussion, the complexity stimulates it: players reformulated the cards, commented on them, and asked other players or nuclear waste experts for help in deciphering the terms used. These moments also tended to create a friendly atmosphere and a sense of collective effort. Many players recognized the playful and participatory nature of the game as a major strength and felt that it could be applied to many other issues and audiences.

Drawing lots for the 'unexpected events' cards

A second adaptation was to increase the attractiveness of the PEP SG by favoring a random selection of game elements. The game unfolds as follows: a player randomly chooses an 'unexpected event' card (Figure 2) and an 'evaluation criterion' card (Figure 3). He/she then places the first one in the time frame of his/her choice, between zero and three hundred years from now (Figure 1). Once these operations have been carried out, the players evaluate the possibility of reaching a *safe terminus* according to the evaluation criterion in relation to the chosen scenario ('directed', 'oriented', or 'open') and the 'unexpected event'.

Figure 2 Example of 'disruptive event' card ©Sitex.

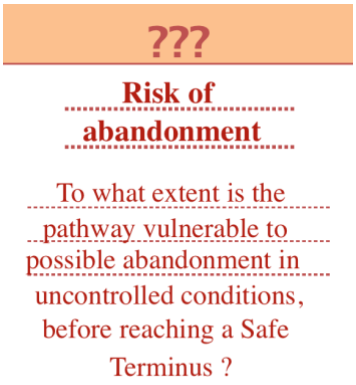

Figure 3 Example of 'evaluation criterion' card ©Sitex.

This modification has two benefits. First, it strengthens the 'game side' by adding a fun factor, as players comment on their luck and the seriousness of the cards they draw. Second, it turns out that randomization helps relieve the pressure felt by the players: chance removes responsibility from an individual player and encourages the emergence of a shared sense of community in the face of an 'unexpected event' that affects them all. Indeed, this collective sense of purpose is necessary to face the question that arises: how to react in a context of uncertainty?

Players welcomed this modification, as randomization allowed them to provoke and nurture debate, repeatedly raise issues they hadn't thought of, and identify different consequences depending on the choice made about the timescale. However, projecting over (extremely) long management timescales is also a challenge for some players, who feel it makes the project less tangible both technically and institutionally.

Challenging players with 'unexpected event' cards and forcing them to choose the timescale they will have to deal with embodies the radical uncertainty that decision-makers face when engaging our societies in difficult-to-grasp timescales.[42] Today's knowledge and data will not be tomorrow's, and this is a major challenge when it comes to defining public policy on RWM.

[42] Sophie Poirot-Delpech, Laurence Raineau, "Nuclear waste facing the test of time: the case of the french deep geological repository project", *Science and Engineering Ethics*, Vol.22 (2016), pp. 1813-1830.

Facing strong constraints first

After the training sessions, it seemed consensual to start the PEP SG with the 'closed' game board, which proposes geological disposal as the preferred management option (Figure 1). This decision was justified by the desire to confront players with strong constraints first, a common preference in scenario-based methods: players found that the 'closed' game board—with clearly defined and identified constraints—limited their choices more, making it easier for them to argue their reactions and (dis)agree with the scenario.

On the other hand, the 'oriented' or 'open' game boards make the game even more complex, as they leave the door open to different options for RWM. Players therefore need to take a more suggestive stance, which is harder to do without a clear diagnosis of the situation. As a result, those boards provoke more contrasted reactions among players: some argue that they make it more difficult to ground the debate due to the increased possibilities, while others praise the opportunity they provide for discussions to get out of the box.

However, some players also expressed frustration with the settings, which did not allow enough freedom despite the more open paths. They highlight that both 'evaluation' and 'unexpected event' cards are powerful tools that can lead players down one path, especially toward geological disposal. While this is considered legitimate in the closed scenario (as it is the imposed solution), some players regret such a restrictive orientation in the case of what should be an open scenario.

Containing the expert interventions

The last adjustments focused on the facilitation of the game. During the training sessions, the facilitator-players highlighted the crucial importance of a facilitation style that effectively balances speaking, does not replace the provision of technical information, and reframes debates when they stray too far from the game's objectives. As a result, two changes were made: first, a more detached facilitation style was proposed to focus on the players' questions and suggestions and encourage interaction. Second, a mixed pair of facilitators from engineering and political science was chosen to ensure the balance and complementarity of their interventions.

The training sessions also revealed that the nuclear waste experts (FANC and Bel V representatives) could provide a lot of additional information before the players took their positions, which quickly created an asymmetry between expert and lay knowledge. Indeed, the priority given

to information produced by experts on possible new contributions from laypeople is a known complexity of public participation processes.[43] To limit this bias and ensure the quality of the exchange between players, the nuclear waste experts were made available *on request*: they were not assigned to a group but were available to answer any questions that arose, thus allowing the players to express their opinions.

Four game changes to create a dialogical space for engaging with uncertainty

The four changes implemented strengthened the core principle on which both the PEP SG and the hybrid forums are based: collectively dealing with uncertain contexts. The game was designed to encapsulate multiple uncertainties and directly confront players with these unknowns, effectively creating a space for (non-)knowledge and expertise to be debated and alternative pathways to be formulated.

The first lesson learned was that creating a dialogical space relies first and foremost on the 'game part' of the PEP SG and its ability to challenge the usual framing of RWM. Instead of relying on the available knowledge of nuclear waste experts, laypeople had to react to the 'unexpected' events (cards) as the starting point of discussion. Similarly, nuclear waste experts were positioned as (not always available) outsiders in the game. These two key components aimed to associate uncertainties as a 'business-as-usual' condition that all players had to constantly address. In other words, the discussion no longer revolved around expert knowledge of RWM, risk calculation, probability assessment of future events, and the presentation of predictive models to assure audiences that every aspect of the program was managed. The goal was to create conditions that would allow each type of event to be considered, regardless of its plausibility or probability, and to observe how all the players—without specific knowledge of nuclear waste—reacted and assessed the situation before proposing several concrete solutions or adaptations to move forward.

By assuming that the unknown and unintended consequences would become a dominant force, a dialogical space including non-experts was created. This, in turn, opened up risks to social definition and construction,

[43] Anne Bergmans, et al., "The participatory turn in radioactive waste management: deliberation and the social–technical divide", *Journal of Risk Research*, Vol. 18, N°3 (2015), pp. 347-363.

making it necessary to extend the debate to a wider public in order to diversify inputs into decision-making.[44]

The next section presents some of the main questions and issues from the players' discussions for dealing with toxic waste programs in uncertain contexts.

Lessons learned from non-experts: 'Living with' uncertainty

First and foremost, the PEP SG raised participants' awareness of the complexity of RWM and the challenges of decision-making in the face of uncertainty, with its multidimensional nature and all its long-term consequences. Indeed, players had to familiarize themselves with technical—but also economic, political, and ethical—concepts to engage with policies.

A first set of players questioned the appropriate attitude to adopt in the face of global uncertainty about the RWM pathway. In response, several players emphasized the importance of taking action: given that the waste has already been produced and could pose a threat to present and future generations, they felt that they had a moral duty to take responsibility.

The type of RWM strategy was also influenced by the need to deal simultaneously with waste and uncertainty. Some RWM options are more durable and provide better safety than others but constrain the future RWM path more than lighter options. For example, some players recognized that irreversible geological storage offers a safety advantage but also a lack of flexibility for future generations.

As debates progressed, the players accepted and assumed that they didn't know everything and had to live with the uncertainties inherent in the toxic waste management project. As one player puts it, "there is no silver bullet. (…) In the end, what's interesting is that it brings us to the eternal problem of politics: making decisions without knowing what the consequences will be." This is the second lesson learned from the non-experts. Like hybrid forums, the PEP SG triggers *collective and generative* learning: rather than simply collecting an aggregation of opinions, the settings force each intervention to add complexity, nuance, or reframe the discussion. By constantly debating, comparing, and reformulating their visions and personal knowledge, participants were confronted with

[44] Ulrich Beck, Peter Wehling, "The Politics of Non-Knowing", in *The Politics of Knowledge*, ed., F.D. Rubio and P. Baert, (Abingdon, Oxon: Routledge, 2012), p. 37.

unfamiliar aspects of the issue they were dealing with. Indeed, knowledge and ignorance are co-produced: the former grows out of the latter, but "non-knowing can also be a consequence of scientific knowledge and its technological application."[45] Any new piece of knowledge acquired (i.e., from nuclear waste experts who provided timely information) raises new unanswered questions.

Lessons learned from the non-experts: deciding under uncertainty

Constantly challenged by unforeseen events that disrupt initial RWM pathways and without having all expert information available, players were nonetheless encouraged to think about the processes that would help them reach the *safe terminus*. In other words, the game was designed to force players to ultimately adopt a *decision-making* mindset. Indeed, the game instruction *'let's keep on playing'*—with or without any scientific knowledge available—allowed more space for fruitful exchanges between players and for pluralistic views to coexist.

While some groups were almost paralyzed by the number of parameters they had to consider to guarantee a safe outcome, players eventually agreed on the need to act. As a result, they developed some concrete strategies for taking positions on complex and high-stakes issues, with or without the support of nuclear waste experts. In this sense, the absence of nuclear waste experts around the table can even be seen as an advantage, as it allows players to systematically identify the questions to be asked and sought before answering the problem. The evaluation criteria and the different sets of assumptions were explicitly formalized. Indeed, despite the lack of information about hazards, laypeople still have a rich conceptualization of risk that reflects valid concerns often excluded from expert risk assessments. Consequently, as the game progresses, experts are also exposed to new ways of *framing* the problems raised by RWM, what Nielsen and Sorensen call the 'unexpected virtue of ignorance.'[46]

[45] Beck, Wehling, "The Politics of Non-Knowing", p. 37.

[46] Kristian H. Nielsen, Mads P. Sorensen, "How to take non-knowledge seriously, or 'the unexpected virtue of ignorance'", *Public Understanding of Science*, Vol.26 (2017), p. 386.

Governance and decision-making: identifying required knowledge

When confronted with the need to propose concrete actions that would help reach a safe terminus, players foregrounded issues of policy evaluation. Many of them recognized the importance of drawing up "*specifications*", assessing "*the pros and cons*" of each choice made in terms of funding, risk, and social or environmental impact, assessing "*knowledge gaps*", and evaluating "*mistakes made*" in the event of an accident. Many players believed it crucial to gather existing detailed, contextualized, and up-to-date information or produce some before making any major decision and moving forward on one or more RWM pathway(s).

Moreover, the very nature of the evaluation process was questioned. The objects of evaluation were multiple and strongly related to unforeseen events: assessing host sites, emerging technologies (and their added value compared to the existing ones), environmental and infrastructural monitoring, and assessing the real potential of future resources could all be the focus of evaluation. The scope and variables to be included also raised questions: when to assess and with what frequency? What are the appropriate levels to make a decision (e.g. local or national level)? On what criteria should decisions be based, and how to establish a hierarchy among them?

Players also discussed the actors responsible for the evaluation and the roles that should be assigned to experts and scientists. The disciplinary composition and independence of a potential scientific council were debated, as was its relationship with political authorities. In that vein, having to decide for (a) RWM pathway(s) calls into question who is legitimate to do so. According to some players, elected decision-makers benefit from a legitimacy that experts and scientists do not have. Nonetheless, players also highlighted that political representatives only held office for a limited time: could that disrupt RWM continuity? Were private companies longer lasting and therefore better suited to the task? Yet, what about their legitimacy or potential diverging interests between public and private structures? Should the public and other stakeholders be consulted?

An interesting movement should be highlighted with this new lesson learned. Players were not unwilling to produce knowledge; rather they were—for those most integrated into the game—at a different level of commitment: they were decision-makers who could *identify* the knowledge and principles required to make informed decisions. In other words, they debated *how to produce knowledge* and what kind of existing and future knowledge was needed to deal with uncertainty.

Remembering: the challenge of ensuring knowledge production continuity

RWM choices will inevitably impact the opportunities and challenges for future generations in relation to radioactive waste. However, the extent to which these choices bind future waste managers varies greatly depending on the nature of the waste disposal. A dilemma emerged during game discussions: remembering the status of the waste and its protective infrastructure versus forgetting it. Each position represents a different relationship between radioactive waste and people.

The first position considers waste and its safety as inseparable from human intervention. In this scheme, remembering waste guarantees transmitting knowledge for safe management. Human involvement in RWM maintains flexibility and openness in the pathway, allowing intervention in waste storage, maintenance, and use of radioactive materials. It also allows diverting the path in case of scientific breakthroughs. Several players consider that treatment techniques may be developed in the future, making storage reversibility crucial. In addition, some participants felt responsible for the management of the waste produced during their lifetime and claimed that forgetting its existence would be tantamount to abdicating this responsibility. The participants who defended this line of argument thus tended to favor reversible waste storage techniques.

The second position argues that irreversible storage should be preferred because human intervention (mishandling, terrorism, or accidental interference) also poses the main threat to the integrity of the radioactive waste storage infrastructure. Accordingly, they propose building a robust infrastructure, conditioning the waste as effectively as possible, and, finally, hiding the storage site from the public. Contrarily to the first argument, players defending this position seem to have more confidence in the technical processes involved in the life cycle of radioactive waste than in human actors.

Several subsequent technical, institutional, and knowledge challenges were raised during game sessions debating this dilemma. The ‘remembering’ position raises challenges about how to protect and transfer the scientific expertise needed to operate, maintain, and transform storage facilities. How can expert knowledge be developed and passed on from one generation to the next if the nuclear industry is dismantled? Do the specialized institutions in the field need to address this long-term problem? Should there be an international organization promoting the production and protection of knowledge? Some players discussed the strategic position of Africa, which could become the guardian of knowledge if it develops its nuclear expertise in the context

of power plant construction. Others mentioned the possible creation of an international library of nuclear waste expertise. In doing so, they demonstrated an ability to think outside the traditional institutional framework of states and their specialized departments.

Path dependency and alternative pathways: relying on existing and future knowledge

During the sessions, players become accustomed to the uncertainty of the pathways and the multiple options available at each step of the RWM process. Faced with unforeseen events, they acquire a sense of anticipation, a way of thinking that leads them to address the main dimensions of the socio-technical challenges at stake. Many players understood and pointed out the path dependency that characterizes the different scenarios of this PEP SG. They were also aware that each storage option has its technical, social, and institutional limits. For this reason, some players proposed to escape the "*depths of uncertainty*" by implementing several storage options at the same time. Building a second storage facility or even preparing a different type of storage is seen as an interesting solution. Other actors were overwhelmed by the uncertainty surrounding the most classical storage solutions and turn to more "*exotic*" ones. For example, they suggested storing radioactive waste in the desert or sending it into space, which led to technical and legal discussions with the nuclear waste experts available during the game session. Multiplying alternatives also raised questions about funding strategies: should states pool together RWM infrastructures? Or involve the private sector?

This lesson shows that a methodological design genuinely taking uncertainties seriously enables players to consider and explore possibilities for multiple RWM pathways. Existing knowledge and currently recommended management options are not neglected, yet they must often be adapted or supplemented to unforeseen events during the game. Therefore, players also identify and rely on other avenues of (future) knowledge production that will allow them to maintain multiple technological options and pathways in the event of additional unforeseen events. In other words, they insist not only on the accumulation of knowledge but also on the diversity and coexistence of research and development programs.

Lessons learned: roles of nuclear waste experts

During the training and game sessions, players asked themselves and nuclear waste experts several questions. During the collective feedback, the former mentioned that they perceived the nuclear waste experts as

providing "*food for thought*", and that they sometimes repositioned themselves according to the information received from those experts.

The players' relationships with those experts varied from one group to another: some involved them very regularly, while others consulted them sporadically. Some followed the guidelines suggested by the experts, while other groups took their cue from them and then moved forward with full knowledge of the facts. Indeed, the role given to the experts, as well as how and when to consult them, was part of the group discussion and left to the responsibility of the players. Hence, once the uncertainties, the ignorance of the other participants, and the limited accessibility to the experts (and through them, to the available knowledge) had been assumed, some groups quickly reclaimed this dialogical space. On the other hand, we found in other groups that the experts' intervention in the discussion was seen as being instrumental: players were piling up questions, asking them how to act, or seeking reassurance about the choices made. In these cases, players generally reintroduced a hierarchy of knowledge, aligning themselves with the experts' proposals.

We also observed that the way the nuclear waste experts responded to the players' questions varied from one expert to another. We identified three forms of expert intervention: the expert '*informant*', the expert '*facilitator*', and the expert '*decision-maker*'. First, strictly following the question asked, some experts provided the most exhaustive possible information on existing scientific knowledge without prejudice. The intervention thus consisted of a list of possible answers to a given question or problem, providing the players with the most complete picture of the socio-technical possibilities and their consequences. The experts aimed to exhaustively *inform* the public.

Some of the experts' interventions were designed to maintain or encourage discussions between participants. These experts asked more questions to the participants, formalizing interconnections between questions and, in some cases, adding more constraints and nuances to push forward collective reflections on one unforeseen event. In this way, questions were sent back to the participants, forcing them to continue thinking and clarifying their thoughts or positions. The experts effectively *facilitated* the debate.

Finally, some experts' answers were more assertive or explicitly reflected the experts' opinions on the topic under discussion. In these cases, as the experts' legitimacy was never in doubt, they were able to steer the discussion through their intervention and effectively *decide* for the players. This type of analytical intervention is worth noting: in the face of uncertainty, it transfers the responsibility for decision-making to the expert.

The players tended to ask the nuclear waste experts more technical inquiries, but governance questions were also raised (Figure 4). Yet, despite the diversity of the questions (some of which involved highly specialized economic, environmental, political, and social expertise), the nuclear waste experts, who are mainly trained in nuclear and engineering sciences, responded indiscriminately to all the questions. Leaning more towards one dimension or the other still depended heavily on the nuclear waste expert. Some took an assertive stance on both governance and technical issues (with a *decision-maker* style), while others preferred to take a more descriptive stance on governance or financial issues (with a *facilitator* or *informant* style).

Technical questions concerned	Governance questions concerned
○ Specific aspects of alternative solutions, e.g.: - the possibility of storing waste under the sea (Group 1) - incineration of waste (Group 3) - cooling of waste (Group 9) - transmutation and its consequences (Groups 3–12) - disposal in the desert (Group 5), in space (Groups 2, 5, 7, 12) - nuclear fusion (Group 12) - environmental, safety and security risks associated with all solutions (Groups 7–9, 12) ○ The current research agendas of nuclear researchers associated with one or other alternative solution. (Group 2) ○ The question of transport. (Group 3) ○ What is (Groups 5–8): - a 'waste package'? - the type of waste the repository is intended to store? - 'final disposal'? - 'geological disposal'? - 'unacceptable risks' in concrete terms? ○ How to organise the monitoring of a repository? (Group 5) ○ How to manage the contaminated nuclear site (Group 5) or the 'damaged' waste already in the repository? (Group 9) ○ What are the types of subsoil considered and the depth of a repository? (Groups 9, 12)	○ The effective implementation of management programmes, e.g., sending waste into space. (Group 2) ○ The relationship between one country and another, as well as the consequences of privatisation. (Group 3) ○ The nature and timing of funding. (Groups 4, 12) ○ The existence of regulatory bodies capable of making binding decisions. (Group 4) ○ Communication in the event of an accident. (Group 12) ○ The competencies of the FANC. (Group 5)

Figure 4 List of questions asked to the nuclear waste experts during the PEP SG

Discussion

This section aims to discuss the added value and the limits of the PEP SG for RWM knowledge production, based on the Belgian experiment. We divided it into three parts in order to question the uncertainty as a precondition for such a sensitive program, the (non-)knowledge co-production and how it distributes responsibilities, and the influence of such an experiment on the Belgian RWM decision-making process.

Uncertainty as a source of lay knowledge

First, we consider that the PEP SG offers a similar added value to the hybrid forum by setting the uncertainty as a precondition before and during the debate (game session). With the game design placing unforeseen and unexpected challenges as the starting point of the discussions, citizens progressively learn to live and deal with uncertainties, forcing them to confront the absence or the lack of knowledge and helping them to integrate that "non-knowledge appears to be a foundational aspect of contemporary knowledge societies based on science and technology."[47]

The rules allow the players to simultaneously address the multiple dimensions of a socio-technical object (RWM is far from being a purely technical issue, and the game offers the opportunity to address political, economic, and ethical questions too) and grasp the complexity of the RWM program.

As in a hybrid forum, the public therefore needs to develop strategies for dealing with such ignorance through *collective and generative learning*, with the occasional support of nuclear waste experts, rather than hoping that it will eventually go away. Results from the Belgian experiment show that players have a rich conceptualization of risks regarding RWM, reflecting on valid concerns that, for some, echo those raised by Belgian stakeholders from the nuclear field in a previous study but,[48] for others, also escape the traditional framing(s) on RWM and explore other avenues. In this sense, uncertainty can also stimulate new thinking and help systematize problem evaluation, including how to frame it and which ethical principles to apply. The absence of scientific and technical knowledge on the part of the players does not mean that they are incapable of reflecting on the problem: they deal with it by identifying the

[47] Nielsen, Sorensen, "How to take non-knowledge seriously, or 'the unexpected virtue of ignorance'", p. 386.

[48] Sacha Frenay, Céline Parotte, "No time to waste: exploring timeprints of radioactive waste management options in Belgium", *TATuP. Journal for Technology Assessment in Theory and Practice*, Vol.31, N°3 (2022), pp. 24-30.

existing and (hoped) future knowledge needed to make an informed decision.

Expert knowledge first?

In the Belgian PEP SG experiment, the analysis showed that there was not a symmetrical *co-production of knowledge* between experts and laypeople. Two hypotheses could be formulated to explain it: the group's characteristics and the type of responsibility that players are prepared to take on in this type of game.

The first hypothesis is that PEP SGs were designed (groups are composed exclusively of laypeople, apart from the facilitators) precisely to avoid the continuous intervention of nuclear waste experts in the discussion. Organizing a direct and sustained relationship between laymen and specialists requires building a collective over a long period of time. Unlike the hybrid forum, the PEP SG participants are not a "concerned group,"[49] i.e. stakeholders who create a community of interest whose bonds are long-lasting and could be reconstituted. In the experimented PEP SGs, players do not exhibit greater concern for RWM than the general population and are likely to participate in only one game session. In other words, they did not claim to have any knowledge to put forward or be heard, as is the case in hybrid forums where each stakeholder is invited, acknowledging and recognizing the multiple areas of expertise around the table. The Belgian players were students, with little or no interest in waste issues prior to the game session.
The second hypothesis is that (non-experts) players mobilize nuclear waste expertise differently depending on the type of responsibility they were willing to take on during the game.

Several players sought and waited for expert knowledge: scientific experts are considered essential before making any decision. In such cases, we have observed that players wait for the experts to frame the issue, and for the experts to ask the right questions or to identify the best options. In short, the players wait for the nuclear waste experts to 'close down' the appraisal[50]. In such a case, the players reproduce a hierarchy between lay and expert knowledge and transfer the full responsibility of decisions to the nuclear waste experts. In Beck's terms, we can say that those players developed strategies of "organized irresponsibilities."[51]

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[49] Callon, "Des différentes formes de démocratie technique", 1998.

[50] Andy Stirling, "'Opening Up' and 'Closing Down' Power, Participation, and Pluralism in the Social Appraisal of Technology", *Science, Technology & Human Values*, Vol. 33 (2008), pp. 262-94.

[51] Ulrich Beck, *World at Risk*, (Cambridge: Polity, 2009).

However, other players—who have best integrated the constraints of the game—have been able to act as decision-makers, effectively identifying both existing and future knowledge needed to make informed decisions and explore multiple pathways. In this case, the experts (if mobilized) are expected to present all possible options, to propose a comparison of options, to provide an overview of the current state of knowledge, to 'open up' the appraisal. These participants do not establish a hierarchy of knowledge, but rather determine and assume responsibility for the type of knowledge required to make their decisions. Players are not unwilling to produce knowledge about RWM (ontological (non-)knowledge about things), but are at another level of commitment: the PEP SG offers new methodological ways to identify things and gain knowledge (epistemological ways of escaping non-knowledge).[52] We could say that the players developed strategies to *organize responsibilities*.

As a nuclear waste expert, it is not a question of taking a position on whether or not a hierarchy between forms of knowledge (expert or lay) is desirable, nor of suggesting a way of hierarchizing knowledge when it exists, confronts, or feeds into one another. It is rather the opportunity to assess the forms of engagement experts are willing to embrace in such debates. In the Belgian experiments, the game facilitators were systematically trained, and the supportive experts were thematic experts from the regulatory systems (most of the time). In the PEP SG sessions, some experts have provided additional information, completed the discussion, suggested new questions, explicitly expressed their opinion, or assumed their non-knowledge on some issues. No matter the forms and the content of the experts' interventions, information provided by the scientific experts was always deemed relevant. Was the players' trust in the nuclear waste experts related to their recognized expertise on the topic or to their administrative role as nuclear 'watchdogs'? Our experiments have highlighted the need to assess more systematically the experts' engagement in the debate—the role performed during the discussion, the roles the expert is comfortable performing, and the role expected from the audience—and the knowledge and non-knowledge they are ready to assume.

Belgian PEP serious game as downstream engagement

The Belgian PEP SG experiment was carried out in a specific context that remains important to examine and understand to assess the scope and potential influence of this type of participative exercise. In Belgium, FANC

[52] Christopher Daase, Oliver Kessler, "Knowns and unknowns in the `War on Terror': uncertainty and the political construction of danger", *Security Dialogue* Vol. 38, N°4 (2007), pp. 411-434.

and ONDRAF have already ratified the RWM method they consider to be the most appropriate, i.e. geological disposal, and have been researching it for more than forty years. At the legislative level, after years of ambiguity, the Royal Decree of 28 October 2022 establishes 'the first part of the national policy' by explicitly establishing geological disposal as the preferred option and laying the first stone towards compliance with the European Directive 2011/70/Euratom. Therefore, despite its publicized purpose of discussing different strategies for RWM, the contribution of the PEP SG comes in, if not at the end, at least after the process of knowledge production by the nuclear waste experts of the regulatory agencies. In a context where both the problem and solution have already been defined, one can question whether the PEP SG fundamentally differs from instances of "downstream engagement,"[53] and whether its outcomes effectively participate in closing the gap between technical and social aspects of RWM.

However, Article 7 of the Royal Decree of 28 October 2022 promotes the principle of 'decision reversibility'—i.e., allowing previous decisions to be reconsidered or reviewed in the light of scientific, technical, social, regulatory, or international developments and changes—and therefore expresses both a willingness to open up decision-making to public debate in the face of uncertainty as well as a possibility to alter prior framings, commitments, and configurations. We emphasize that methods such as the Belgian PEP SG could (re)open the debate on RWM and, as a result, make its socio-technical pathways more robust, thus supporting this principle of 'decision reversibility'.

Conclusion

Serious games can be a relevant method for envisioning futures and assessing expert and lay knowledge under different scenarios for highly sensitive and complex policies. This paper examines a particular SG applied to the long-term future of high-level radioactive waste management: the Pathways Evolution Process (PEP) SG. Developed at the European level by regulators and their technical support, the initial aim of the game was to ensure the robustness of their safety case and to enhance dialogue with civil society and other stakeholders.

By evaluating its testing in the Belgian context through the analytical lens of the *hybrid forum*, we stress that the PEP SG is an interesting method for raising awareness of the complexity and interdependencies of multidimensional RWM, for increasing dialogue between nuclear waste

[53] Bergmans, et al., "The participatory turn in radioactive waste management: deliberation and the social–technical divide", 2015.

experts and civil society, and for taking lay knowledge seriously. We emphasize that the players accepted having to *live with* the uncertainties inherent in toxic waste management projects and that they developed different strategies for doing so. *Making decisions under uncertainty* goes hand in hand with the production of knowledge and ignorance. In our case, deciding means considering a mode of governance that constantly reassesses the need for expert and lay knowledge, depending on unexpected events. We have shown that laypeople have a rich conceptualization of risk that enables them to identify and justify in detail the type of knowledge required for each uncertain situation (format, responsible persons, actors to be involved), as well as how and when to produce it. While the action is strongly linked to existing knowledge (and the path dependency resulting from already favored technological options), players also take account of both future knowledge and accumulated RWM knowledge (e.g., options not favored) that may propose alternative paths. Indeed, they insist on the need for a diversified knowledge production covering several RWM pathways. Besides, for them, deciding also means remembering, maintaining, and sharing the knowledge produced over the long term of the program (beyond the end of its implementation).

In our view, the PEP game session *trains the participants to embrace uncertainty* and to discuss how to jointly address the multiple challenges that are (im)posed to all actors. This relies on the main feature of the game design: considering unknowns and unforeseen consequences as 'business-as-usual' conditions for RWM and creating additional conditions to accentuate uncertainty. It provides a framework that goes beyond contrasting positions for or against a management option or the nuclear program, the plausibility of an event to occur, and the persistent hierarchy between expert and lay knowledge in favor of the former.

Although several unforeseen events have already been encountered in countries actively pursuing a long-term waste management program, the game design cannot be considered a ‘one-size-fits-all’. RWM programs are first and foremost ‘waste-site stories’, far from being applied in a generic way but adapted to the national and local contexts in which they take place. The type of waste produced, the status of spent fuel, the historical and current production sites for radioactive waste, and the profiles of the public concerned, to name but a few, are all recurring questions that require local or national answers. In our view, both the depth and quality of the discussion as well as the collective learning depend on the game’s ability to keep RWM complex in simple terms, and the seriousness of the game will remain if the initial national constraints and cards imposed on the players are regularly updated according to (future) substantial changes in RWM policy.

Similarly, the nuclear waste experts were not to provide one straightforward answer to every question raised during the game sessions. Rather, the debate involved both active listening to the laypeople's expectations and multiple opportunities for the expert to make his current (un)knowledge visible. We highlight that the production of lay knowledge encounters that of nuclear waste experts, and underline two ways of integrating the latter: players either disengage and let the experts make the final decision, or better organize responsibilities by putting the experts at the service of a decision taken by the participants. Our analysis shows that both the (re)production of a hierarchy between expert and lay knowledge and the subsequent transfer of responsibility depend strongly on the form of the experts' interventions—either informing, facilitating, or deciding for the players—as well as on the knowledge and non-knowledge they are willing to assume. It is therefore crucial to systematically assess how experts engage in such dialogical spaces.

Finally, the way in which experts integrate the outcomes of these game sessions into their practice and knowledge production also deserves more attention. How do the outcomes of discussions with stakeholders and audiences *actually* affect the safety culture and the handling of safety cases? How do these discussions change (or not) experts' initial thinking about how to respond to ever-increasing economic, social, technical, and political constraints? The evaluation should therefore focus not only on the timing and content of the SG sessions but also on how these sessions influence or modify the regulatory principles and practices of the management program. Indeed, if used for instrumental purposes, this type of method can have the opposite effect to that intended: it can become a promotional activity aimed at gaining acceptance for a preferred waste management program, and miss the opportunity to make its socio-technical pathways more robust. A genuine involvement of non-experts in knowledge *co-production* is therefore required to *systematically* address uncertainties.

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Building a culture of responsibility: education for disarmament and non-proliferation

Jean Pascal Zanders[*]

Abstract

Controlling the development, utilization, or transfer of dual-use technologies underlying non-conventional weaponry has become a significant issue from a disarmament and non-proliferation perspective. However, evidence suggests that stakeholder communities often lack awareness of technology transfer risks and their responsibilities in preventing or mitigating their consequences.

This article examines the case of the master's course on chemical, biological, radiological, and nuclear (CBRN)-relevant dual-use technology transfer controls developed within the framework of the European Union-funded Targeted Initiatives on "Export Controls of Dual-Use Materials and Technologies" as part of efforts to address these challenges. The paper outlines the process of developing and implementing this modular course, successfully implemented in several former Soviet republics in Central Asia and Southeast Europe.

Emphasizing the preference for education over more traditional training approaches, the article discusses how the course aims to enhance awareness and foster responsible behavior among stakeholders. In addition to assisting academic institutions in setting up the courses and advancing knowledge among professors, significant effort was invested in engaging decision-makers and various stakeholder communities to broaden the educational initiative's foundations. Under the organizing theme of building a culture of responsibility, these interactions proved to have significant educational value and contributed to the core ambitions of local ownership

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and sustainability.

In conclusion, the article argues that sustained educational efforts and collaborative initiatives are essential for addressing challenges posed by dual-use technology transfers and contributing to global security and non-proliferation efforts.

Keywords
CBRN, Capacity-building, Disarmament, Dual-use technologies, Education, Export controls, Non-proliferation, Technology transfer.

Introduction

Controlling the development, utilization, or transfer of dual-use technologies underlying non-conventional weaponry has emerged as a significant issue in the realm of disarmament and non-proliferation.[1] It is pertinent to acknowledge that the control of chemical, biological, radiological, and nuclear (CBRN) weapons has evolved beyond being solely the purview of states. Historically, particularly in the earlier stages of atomic weapons development, states predominantly held control over such technologies. However, contemporary realities reflect a notable shift. A lot of scientific research, technology development, and production occurs in universities and private companies. Technology diffusion through trade, staff turnover and migration, widening education abroad, and expanding virtual project collaboration mean that sub-state, international, and transnational actors are crucial to today's technology transfer processes. Governments have increasingly shifted responsibilities for the safe transfer of potential dual-use technologies to those agents. Reports from meetings of state parties or review conferences of weapon control treaties emphasize the responsibilities of natural or legal persons to prevent unauthorized access to certain types of technology, including through the adoption of workplace security and safety measures. The recommendations in such reports are an excellent motivator for substantive educational engagement with key stakeholder communities.[2]

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[1] In the context of the present paper, dual-use technology comprises technologies with "current or potential military and civilian applications". Molas-Gallart, J., "Dual-use technologies and the transfer mechanisms", in *Technology Transfer,* Schroeer and Elena eds., (Ashgate: Aldershot, 2000), p. 5.

[2] The reports and comments during formal meetings have over the past years led to diverse education-oriented activities to engage with young students and professionals and stakeholder communities. In the biological field: "UNODA convenes a workshop for young scientists to foster networks on biosecurity in the Global South", UNODA, August 8, 2019, https://disarmament.unoda.org/update/unoda-convenes-a-workshop-for-young-scientists-to-foster-networks-on-biosecurity-in-the-global-south/; "NTI|bio Bolsters Young Scientists and Promotes Youth Engagement at the 2021 BWC Meeting of Experts", NTI, September 14, 2021, https://www.nti.org/news/nti-bio-bolsters-young-scientists-and-promotes-youth-engagement-at-the-2021-bwc-meeting-of-experts/; "Youth for Biosecurity, 2022 Cohort", UNODA, https://disarmament.unoda.org/youth-for-biosecurity-2022-cohort/; "Youth Recommendations for the 9th Review Conference of the Biological Weapons Convention", YouTube, November 3, 2022, https://www.youtube.com/watch?v=9DhLVbj8Noc. Because no international organization exists for the Biological and Toxin Weapons Convention, the initiatives are sponsored by state parties, scientific associations, and civil society activities and take place under the auspices of the United Nations.
In the chemical field, the Organisation for the Prohibition of Chemical Weapons (OPCW) set up the Advisory Board for Education and Outreach (ABEO) in December 2015. Since the start of its work in 2016, the ABEO has developed many strategies for both in-person and virtual education and engaged with industry, scientific communities and academia,

This article outlines the design and development of a university master's course focused on CBRN-relevant technology transfers and its implementation in different national, cultural, and educational contexts.[3] Central to this educational endeavor is the ownership by local project partners, such as universities, research institutes, or their representatives, and the long-term sustainability of the course, which became the primary objectives of the educational project. Despite challenges posed by the COVID-19 global pandemic and the Russian invasion of Ukraine in February 2022, adaptation led to different experiences, including enhanced networking among various academic and scientific institutions. The establishment of collaborative initiatives reinforced ownership and sustainability, significantly advancing the ultimate objective of promoting governance of dual-use technology transfers under the organizing theme of building a culture of responsibility.[4]

Underlying the idea of a university master's course was a choice for education over traditional training and capacity-building activities. However, education involves more than merely offering courses at academic institutions and preparing lecturers for the task. It entailed preparing the ground through outreach to key stakeholder groups in academia, research institutions, industry, and commerce, as well as promotional activities supporting student enrolment. Moreover, it required continuous engagement with decision-makers at levels of university faculties and rectorates, as well as relevant government agencies. Ultimately, these activities and engagements proved educational in their

https://www.opcw.org/about/subsidiary-bodies/advisory-board-education-and-outreach.

In the nuclear area, the International Nuclear Security Education Network (INSEN) arose around the International Atomic Energy Agency (IAEA) as a network of young scientists and academics in 2010. Tariq Majeed, et al., "The INSEN experience, by INSEN Chairs", *International Journal of Nuclear Security*, Vol. 6, article 3 (July 2020). The Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) launched the CTBTO Youth Group in February 2016, thereby establishing a global network. https://www.ctbto.org/resources/for-civil-society/ctbto-youth-group.

[3] In this context, the term master's course refers to a comprehensive educational program designed to provide in-depth knowledge and skills in a specific field of study, typically at the graduate level. Originally conceived as a standalone master's course comprising 60 credits under the Targeted Initiative, the development process led to adaptations to accommodate various educational contexts.

[4] The concept of organizing theme refers to a central theme around which all activities are structured to maintain cohesion among those activities (and participating institutions). This concept is also discussed in: "Report on the Role of Education and Outreach in Preventing the Re-emergence of Chemical Weapons", ABEO-5/, Organisation for the Prohibition of Chemical Weapons, (12 February 2018), p.6, accessed 16 November 2023. https://www.opcw.org/sites/default/files/documents/2019/03/abeo-5-01_e.pdf

own right and prepared the ground for sustainability and local ownership, two primary objectives of this educational project.

The paper starts with a brief overview of the origin of the Targeted Initiatives, the EU-funded programs aimed at addressing the challenges surrounding the control of dual-use technologies transfer related to CBRN. It also situates the education work package within the Targeted Initiatives. Subsequent sections delve into the education work package in more detail, exploring the elements contributing to the preference for an educational method over a more traditional training program. The article then discusses the project initiation and the reasons for adopting a modular approach to the course design. The final part considers how networking and local capacity-building contribute to local ownership and sustainability before closing with some conclusions.

The EU Targeted Initiatives

In 2017, the EU initiated a program to design and implement new ways of enhancing export controls governing the transfer of dual-use technologies underlying the development and production of CBRN weapons. Building on achievements and insights from the EU Partner to Partner (P2P) Export Control Programme—which is the EU outreach export control program, started in 2004 and renamed P2P in 2016[5]—the newly launched Targeted Initiatives on "Export Controls of Dual-Use Materials and Technologies" sought to achieve two primary objectives.[6] Firstly, it aimed to engage the academic community in the CBRN knowledge area. Secondly, it aimed to encourage partner countries to implement and enforce effective export controls. The European Commission funded the program in support of the EU's Global Strategy (2016) and Strategy Against the Proliferation of Weapons of Mass Destruction (2003).[7]

The European Commission entrusted the International Science and Technology Centre (ISTC) in Astana, Kazakhstan, and the Kyiv-based

[5] "EU P2P Export Control Programme", Chemical, Biological, Radiological and Nuclear Risk Mitigation, European Union, accessed 16 November 2023, https://export-control.jrc.ec.europa.eu/projects/Dual-use-trade-control.

[6] "On other EU activities on Dual-Use Export Controls", EU P2P Export Control Programme, European Union, accessed 28 April 2024, https://cbrn-risk-mitigation.network.europa.eu/eu-p2p-export-control-programme/dual-use-trade-control_en.

[7] Council of the European Union, Strategy Against the Proliferation of Weapons of Mass Destruction, Document 15708/03 (Brussels, 10 December 2003); European Union. (2016). "Shared Vision, Common Action: Strategy for the European Union's Foreign and Security Policy", European External Action Service, Brussels, June 2016.

Science and Technology Centre in Ukraine (STCU) with implementing the Targeted Initiatives.[8] ISTC engages Central Asian and Southeast European countries (primarily Armenia, Georgia, Kazakhstan, Kyrgyzstan, and Tajikistan), whereas STCU serves Georgia, Ukraine, Azerbaijan, and Moldova (GUAM).[9]

An international coalition of states, including the United States (US) and the EU, set up both science centers in the mid-1990s, inspired by the goals of the US Comprehensive Threat Reduction Programme initiated in 1991.[10] During the Cold War, the Soviet Union developed and produced large chemical, biological, and nuclear arsenals in a sprawling military-industrial complex. After its breakup, the weapon depots, training sites, and research, development, and production installations became scattered over many fledgling states. Moreover, the centralized command-and-control system overseeing infrastructure and activities fell apart. From their inception, the science centers prioritized engaging with engineers, scientists, and technicians who had been involved in the former Soviet weapon programs. Concerns arose as these highly educated and trained personnel lost their social status, privileges, and income, raising fears that they might seek to sell their CBRN-related knowledge, skills, and expertise to foreign countries. Today, the ISTC and STCU continue to provide, among other things, financial assistance and facilitate collaborative civilian technical research and training to new generations of engineers, scientists, and technicians.

The EU Targeted Initiatives thus fit into the core mission of both science centers. Although the ISTC and the STCU operated under separate contracts with the European Commission, both programs ran concurrently. The ISTC initiated its program in October 2017, while the STCU commenced in February 2018. Both projects ended in December 2023. While there were some variations in implementation, mainly due to regional specificities and specific needs and expectations of participating institutes, the core set-up of the work packages was common to all project participants.

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[8] For further information, see the official website: https://istc.int. The webpage dedicated to the Targeted Initiative is https://www.istc.int/export-control.

[9] International Science and Technology Center in Ukraine, accessed October 28, 2023, https://www.stcu.int/. The webpage dedicated to the Targeted Initiative is http://www.stcu.int/tiexpcontrol. (Note: the STCU site is occasionally down because of the war.)

[10] "Fact Sheet on DOD Cooperation Threat Reduction (CTR) Program", US Mission Geneva, April 4, 2022, https://geneva.usmission.gov/2022/04/04/fact-sheet-on-dod-cooperative-threat-reduction-ctr-program-biological-threat-reduction-with-partner-countries/#:~:text=DoD%20CTR%2C%20also%20known%20as,evolve%20into%2015%20sovereign%20states.

Initially, the Targeted Initiatives envisaged five work packages, one of which did not materialize. The four that proceeded addressed: establishing a network of scientists (WP2); developing a master's course on export controls (WP3); providing PhD grants (WP4); and conducting outreach to industry (WP5).[11]

For each work package, a person with proven relevant expertise was responsible for setting specific objectives within the Targeted Initiatives' overall framework, developing appropriate methodologies, and deploying activities to achieve the goals. A general coordinator monitored progress in each work package and ensured that the work package leads remained appraised of initiatives and results in the other project components. Additionally, the overall coordinator also encouraged the work package leads to identify and exploit possible synergies among them.

This article will exclusively focus on WP3, delving into the development and implementation of the master's course on export controls. Before discussing the details of the course, the rationale behind preferring education over more traditional training approaches will be examined below.

The preference for education

The master's course developed under the Targeted Initiatives seeks to enhance the general understanding of the security concerns about dual-use technologies. Its objectives include enabling participants to understand how these technologies might affect their professional roles and individual responsibilities. Moreover, the course intends to empower

[11] Details on the four packages envisaged by the Target Initiatives are as follows. WP2 Network of Scientists: this package aimed to raise awareness about CBRN-relevant dual-use technology transfer controls among the scientific and academic communities. It also addressed responsibility and ethics in science and research. WP3 master's course on export controls: this work package focused on the development of a fully credited university course to educate different stakeholder communities on the risks of dual-use technology transfers and their responsibilities under an export control system.WP4 PhD Grant: the objective of this package was to encourage students to develop a PhD research project in the field of dual-use technology transfer controls and apply for a grant that helped to pay for the time spent as a researcher and research-related costs. The selected students conducted their PhD research at a university with the necessary academic expertise in the EU and, if successful, graduated from that university. WP5 Outreach to Industry: this package aimed to raise awareness among business communities and industry and promoted internal compliance programs. It also developed handbooks and implemented commodity classification courses in collaboration with customs, specialized associations, and non-governmental organizations.

them to identify and address issues associated with dual-use technologies.

While various international organizations, government agencies, academic and scientific institutions, and civil society organizations undertake some education in disarmament and non-proliferation, most of those initiatives primarily focus on building professional capacity, raising awareness, or assisting with designing, developing and implementing legal and regulatory measures in line with international obligations concerning CBRN weapons. Despite these efforts, the observation persists that academics, scientists, students, and stakeholders in private industry and commerce are unfamiliar with international legal instruments and national laws and regulations governing their activities. Consequently, they may lack insight into how their activities with dual-use potential could—inadvertently—contribute to weapon development and the proliferation of technological capacities to countries or other entities seeking proscribed weapons.

The principal cause for such lack of awareness is the absence of formal instruction in present or future risks about scientific research or technology development beyond those relating directly to workplace activities. Their knowledge about international legal instruments, such as disarmament treaties or non-proliferation arrangements, or national laws and regulations implementing them may range between rudimentary and non-existent. Even if some level of risk consciousness is present, representatives from institutions, companies, or even government agencies may be hesitant to acknowledge any connection between their work and weapon development. This knowledge deficit about broader governance frameworks extends to ethical debates on the social implications of researching, developing, manufacturing, and trading certain technologies.[12] It affects how new proposals are assessed and monitored for risk or activity results evaluated. Methodological approaches and organization of capacity-building activities may explain the persistence of such lack of awareness among key stakeholder communities:

- Most courses are short-term, often limited to a few days or a week.

[12] D. Rychnovská, "Governing dual-use knowledge: From the politics of responsible science to the ethicalization of security", *Security Dialogue*, Vol. 47, No. 4 (August 2016), pp. 310-328. M. Himmel, "Emerging dual-use technologies in the life sciences: Challenges and policy recommendations on export control", *Non-Proliferation and Disarmament Papers*, No. 64 (September 2019), p. 15. S. Vinke, I Rais, and P. Millett, "The Dual-Use Education Gap: Awareness and Education of Life Science Researchers on Nonpathogen-Related Dual-Use Research", *Health Security,* Vol. 20, No. 1 (February 2022), pp. 35-42.

Even if specific courses make up part of a broader or longer-term package, there is limited follow-up with course participants to assess how much they have internalized the new information or practices.

- Capacity-building courses are not part of continuous education. This has three significant implications.
    - First, their organization may be a one-off event or repeated annually. If multiple events occur in a single year, their reiteration may target other states, regions, linguistic communities, or institutions.
    - Second, a capacity-building course cannot follow a participant's progression in knowledge, expertise, and experience, meaning that the opportunities for that person to fully assimilate the value of the course content concerning current or future activities may be limited.
    - Third, the more specific the course contents, the more challenging a course participant may find their application to different contexts.
- Many courses follow a train-the-trainer model in the expectation that course participants will convey the new information or practices to a broader audience. Usually, the course organizer will not follow up with any quality assessment of how or to whom course participants transfer their newly acquired knowledge and expertise. In addition, the extent to which course participants can engage with peers outside their immediate work environment remains unclear. While the train-the-trainer approach seeks multiplication effects, there is no guarantee of follow-on activities taking place or, if they do, of educational quality in those sessions.
- There is no guarantee that participants are the most appropriate to take the course. In many instances, governments or institutions will nominate, upon invitation, an individual to follow the course based on criteria beyond the control of the course organizer.
- Sponsors and implementors of capacity-building courses cannot assess in advance the likelihood that participants may influence practices in an institution or company, nor do they have formal indicators or relevant information to evaluate transformation in workplace practices.

In 2017, the Advisory Board on Education and Outreach (ABEO) of the Organisation for the Prohibition of Chemical Weapons (OPCW) set out to evaluate educational methodologies and recommend specific approaches in support of the OPCW's objectives, namely eliminating and precluding the use of chemical weapons and preventing their re-emergence. The ABEO comprises 15 persons from different countries on all continents with expertise in education, treaty implementation, and engagement with stakeholder communities. In February 2018, the OPCW

published its Report on the Role of Education and Outreach in Preventing the Re-emergence of Chemical Weapons.[13] The present author then chaired the ABEO.

One of the key ABEO recommendations holds that target audiences should discover the issues for themselves, how they affect their work, and, consequently, why they should seize them. Answering those questions represents a significant educational process in its own right. Furthermore, educational exercises have shown that each one of the professional categories may have specific awareness of issues relevant to their work field. Still, people may not realize that colleagues and partners from other disciplines can face similar challenges in different contexts. Consequently, besides being multi-disciplinary, the course also has to be cross-disciplinary.

As a general conceptual framework, the insights and recommendations in the report inspired and guided the development and implementation of the education work package. Regular briefings to the ABEO members on progress and experiences with the Targeted Initiatives also yielded valuable comments, suggestions, and insights.To summarize, making academics, scientists, students, and stakeholders in private industry and commerce conversant with international legal instruments and national laws and regulations on dual-use activities and technologies that could contribute to developing CBRN weapons is but a first necessary step in an educational process. It is more impactful when those stakeholder communities transpose the formal rules into practical guidance for staff. Besides participation in capacity-building courses, the latter goal requires institutional backing to implement such guidance in daily work activities. As part of the educational undertaking, the capacity-building project must engage key decision-makers in universities, research institutes, companies, and government agencies to let them discover why certain routine practices prevent misuse or inadvertent transfers of science and technology. This multi-stakeholdership supporting the master's course explains the necessity for framing and promoting the organizing theme "building a culture of responsibility".

[13] Advisory Board on Education and Outreach, Organisation for the Prohibition of Chemical Weapons (2018). Report on the Role of Education and Outreach in Preventing the Re-emergence of Chemical Weapons. ABEO-5/1 (12 February), accessed November 16, 2023, https://www.opcw.org/sites/default/files/documents/2019/03/abeo-5-01_e.pdf

Education work package: the master's course on export controls

The initial assignment under the education work package was straightforward: designing and implementing a master's course on CBRN-relevant dual-use export controls. The projected running time was two years. Despite the possibility of extensions, the time frame was short to design a course from scratch and incorporate it into a university curriculum. Work began in February 2018, and the Taras Shevchenko National University (TSNU) in Kyiv started teaching the course in October 2019.

In these sixteen months, several other, more refined goals emerged or became better articulated. Two of the most important ones were sustainability and the transfer of ownership to the local partner. Both objectives were intertwined yet demanded separate sets of preparatory actions.

Sustainability implies that the partnering university would continue to teach the course even after project sponsorship and financial support ends. The contracts the academic institutions participating in the Targeted Initiatives signed with the ISTC or STCU reflected that undertaking. More importantly, the objective required the development and execution of several sustainability strategies. On the one hand, the new course had to attract the interest of sufficient students. Therefore, actively reaching out to the student body with a view to their enrolment in the future course became an early and urgent necessity. In the months preceding the course launch, the local project partner at the TSNU held information sessions. They also organized briefings with the overall coordinator of the Targeted Initiatives and the education work package lead and set up sample lectures open to students and academic staff. On the other hand, they also arranged meetings with university decision-makers on the faculty and rectorate levels. These appointments allowed the overall coordinator and work package lead to explain the need for a master's course on dual-use technology transfer controls and highlight the course's relevancy for the participating university in the short and longer terms. Their invitation as speakers at internal seminars for faculty members, academics, and lecturers enabled them to communicate with faculty and university-wide audiences to build broader institutional receptibility for the proposed master's course. Most of these activities took place in parallel with the development of the curriculum. They also aided with the course design by contributing to a clearer understanding of the educational needs and practices.

To help launch the master's course at the TSNU, a student sponsorship initiative covering university enrolment fees supported the initial recruitment drive. However, it was time-limited from the outset. The money allocation per student was halved in the second year of teaching. The initiative enabled the local project partner to broaden student recruitment and meet one of the university's minimum requirements for continuing the course.

Transfer of ownership is crucial for achieving sustainability, but it involves different actions. One aspect was investment in building capacity. Intensive lecture sessions for professors prepared them for teaching in the new master's course.

A second facet was the identification of potential key stakeholders in the master's course among the scientific community, industry, and concerned government agencies. It also included facilitating interactions between the local project partner and those stakeholders. Several strategic reasons called for these types of activities. First, expressing stakeholder interest in the course because of the direct benefits graduate students would bring those stakeholders is a powerful argument to present to university decision-makers. Second, direct interactions with the different actor communities become a primary source of information about future job opportunities, student internships, and trainee positions. Having this type of job market intelligence and being able to offer positions for hands-on training make for a strong student recruitment argument. Third, some of those stakeholders might become sources for future funding via subsidies or grants. Finally, members from assorted stakeholder communities could also become expert lecturers in the master's course, thus offering students first-hand knowledge, experience, and expertise.

Two additional strategic levers emerged after the Targeted Initiatives entered their third year: building national and international academic networks and setting up a research base. Student numbers were an important criterion for starting and sustaining the CBRN-relevant dual-use technology export control course. At the TSNU, the person in charge of organizing the course decided from the outset that the lectures would be open to students from other faculties and academic institutions. This choice proved fortuitous when the COVID-19 pandemic started shutting down social and economic life in February 2020, leading to European border closures.

Ukraine closed its borders in the middle of March, and the final set of lectures on export controls had to be delivered virtually. The pandemic also posed an immediate threat to continuing the educational initiative in the 2020-2021 academic year and beyond. The solution came in the form of extra-mural classes open to anybody in Ukraine registering for the

virtual lectures. Still, the initiative required coordination with other Ukrainian academic institutions and promotion of the course among their students. The process of clarifying the process and specific objectives of extra-mural teaching during the late spring and early summer of 2020, together with the outreach activities by the TSNU person in charge, was the de facto origin of the networking objective in the education work package of the Targeted Initiatives. Development of its strategic concept continued throughout 2020 and into 2023.

The Targeted Initiatives ended in December 2023. Six target countries—Kazakhstan, Kyrgyz Republic, and Tajikistan in Central Asia and Georgia, Moldova, and Ukraine in Southeast Europe—adopted one or more modules of the master's course developed under the Targeted Initiatives. In all instances, national education authorities accredited the programs.

Designing and developing the master's course

Whereas the Targeted Initiatives foresaw from the outset the introduction of a master's course on CBRN-relevant export controls, they identified few parameters beyond a general statement that it would offer the package to universities for inclusion in their curriculum. It raised multiple questions. Who would implement the course, or more precisely, which university faculties may be involved? Who would be the target audiences: students taking their first university degree, students with prior degrees seeking to specialize in non-proliferation and export controls, or professionals required to enhance or update their knowledge? Which issue areas would the master's course cover? What prior knowledge about CBRN weapons and their underlying technologies would the target audience possess or require? A final question, which eventually became the point of departure for the course design, concerned the contents.

A mind-mapping exercise

The course design began with a mind-mapping exercise aimed at thoroughly identifying all potential issues to be covered in the master's course. These issues were then grouped into broad topics. Within each topic, content-related hierarchies were established, ranging from top-level considerations to issue details. Additionally, the exercise built linkages between the different branches and sub-branches where relevant. The mind map eventually comprised eight main branches organized into two parts: *topics* and *strategies*.

Topics contained five branches:

- *Basic knowledge* covers the CBRN weapon spectrum and introduces core concepts in disarmament, arms control, and non-proliferation.
- *Dual-use technologies* introduce the concepts of technology and processes related to technology innovation. It addresses how technology relates to disarmament, arms control, and non-proliferation and inserts the notions of single, dual-use, and tangible and intangible technologies.
- *International control regimes* cover the range of legal instruments affecting CBRN weapon technologies and their transfers from global and regional treaties to international sanctions and embargoes, as well as plurilateral arrangements to prevent their proliferation.
- *Understanding responsibilities* addresses risk and threat perceptions and the responsibilities different categories of actors each have in preventing or mitigating such risks and threats. The branch also covers the relationship between the weapon systems and their underlying technologies and innovation processes. (See Figure 1 for a visual representation of the organizational structure of the mind map branch 'Understanding responsibilities', which illustrates branches of topics and strategies).

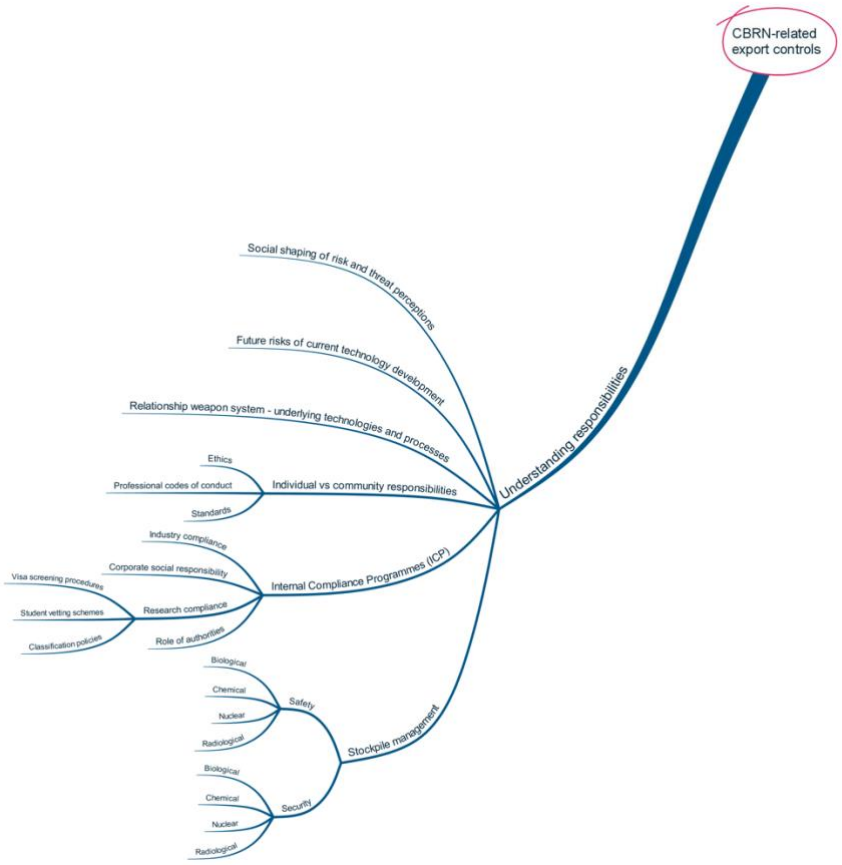

Figure 1 The mind map branch "Understanding responsibilities"

Strategies comprised three branches:

- *Educational strategy:* identifies the central parameters for the course grouped along four core questions: what, why, how, and who?
- *Transfer controls:* lists the various actors and stakeholders involved in regulating and implementing dual-use technology transfers.
- *Economic relationships:* concerns the different partners in domestic and international technology transfers and the various transfer patterns.

Given the intention to deploy the master's course in Central Asia and the GUAM countries, the anticipated varied professional and cultural backgrounds of course participants posed considerable challenges from the perspective of educational methodology.

Some of the early workshops organized by the ISTC and STCU in 2018 yielded a clearer vision of potential users, i.e., the institutions planning to introduce the course. Moreover, the discussions revealed that those potential users envisaged different course offerings. These included short introductory sessions, one-week short courses, and two-week intensive executive courses for professionals, government functionaries, and research institutes working with or on technologies with potential dual-use characteristics that might contribute to CBRN weapon development.

Discussions with university representatives pointed to multiple possible configurations for the master's course, most of which involved integrating the proposed lectures into existing curricula rather than establishing a standalone course of study leading to a specialized master's degree. They also had elective packages in mind.

Learning of these different contexts led to a modular course design approach. Several self-contained learning units could meet the various requests for course configuration on varying levels of expertise.

The modular construction of the master's course

The master's course on CBRN export controls concerning dual-use materials and intangible technologies was conceived as a fully credited program.[14] Structurally, it consists of modules, which, while part of the

[14] While the initial goal of a 60-credit standalone master's course was not fully realized, the term "full credit" persisted in subsequent writings and presentations. It is worth noting that the term "fully credited university master's course" may better convey the

bigger whole, are also self-contained teaching units. As such, a local project partner can integrate one or more modules in an existing master's course, or the modules can be deployed independently or combined according to the educational needs of specific target groups, such as professionals or government officials. A module comprises ten to twelve academic lectures of two hours each.

The master's course developed under the Targeted Initiatives contains nine modules divided into three segments, namely two Introductory Modules (IM), four Substantive Modules (SM), and three Seminar Modules (SE).

The introductory modules

The original and primary purpose of the introductory modules was to enable anyone interested in advancing their knowledge in weapons control, technology transfer, and export controls to participate in the course. By spring 2018, the preparatory workshops organized by the ISTC and STCU had already revealed that knowledge about transfer controls, their foundations in international and domestic law, and the respective responsibilities of assorted stakeholders in academia and scientific communities, commerce and industry, and government was far from universal. Moreover, the interest in hosting the course by representatives from different academic disciplines or types of institutions suggested the need for more widespread, shared knowledge. The ambition to open the export control course to students from other faculties reinforced the latter point. Two introductory modules were organized as follows:

- *IM1: CBRN basic knowledge and concepts* introduce course participants to the basic concepts relating to CBRN weapons and their control; the concept of dual-use technologies and the challenges these pose from a policy perspective; and the formal, multilateral treaties and other arrangements set up to prevent their misuse.
- *IM2: Frameworks, instruments and responsibilities* aims to provide a holistic overview of frameworks and mechanisms relevant to CBRN export controls, their respective objectives, and areas of operation. Those instruments also engender responsibilities for different categories of actors. This module introduces those responsibilities and links them to broader societal and policy contexts.

ambition of the program while acknowledging its status may vary depending on the university adopting the course.

In June 2019, the master's course went through an intensive, two-week test run in Astana, Kazakhstan and yielded important additional insights for arranging the basic modules. Specifically, prior elementary knowledge about the technologies concerned, the regulatory environment, or transfer processes could not be assumed. Moreover, methodologies to search pertinent information (e.g. via the Internet) were rudimentary. For instance, they lacked insight into how to set up structured searches and verify the returned information. Several participants also conducted searches on a mobile phone, unaware that the screen's small size impeded complex search operations.[15] These experiences were informative on how to set up active learning sessions while teaching the modules.

The substantive modules

Four substantive modules were organized as follows:

- *SM1: Threats, risks, and their mitigation* offers an in-depth analysis of the various ways in which threats and risks related to CBRN materials and technologies manifest. It explores the different mechanisms through which technology transfers may deliberately or accidentally occur. Additionally, it establishes connections between threats and risks with various frameworks and instruments designed to counter them. As an introduction, it also delineates the roles played by multiple national implementers and categories of national and international actors.
- *SM2: Transfer controls (international level)* addresses the international regulatory level. The historical analysis introduces students to the origins of export control regulations and also places their evolution in the context of international developments. The module discusses the various international instruments and their respective approaches under which a state must prevent proliferation activities.
- *SM3: Transfer controls (national level)* shifts the focus to the national regulatory level. It educates students on the process of transposing international obligations into national legislative and regulatory frameworks, and discusses the options available to legislators and regulators. Finally, it emphasizes the importance of engaging and educating key stakeholder communities on their specific

[15] J. P. Zanders, "Disarmament education: Road-testing a master's course on CBRN dual-use technology transfer controls", the Trench Blog (July 21, 2019), https://www.the-trench.org/disarmament-education-road-testing-a-masters-course-on-cbrn-dual-use-technology-transfer-controls. The observations about the internet searches in different locations have led the author to develop a practical guide on structured internet searches, which should become available in the summer of 2024.

contributions or responsibilities regarding preventing CBRN proliferation.

- *SM4: Promoting responsible behavior* addresses advances in science and technology and their potential contribution to CBRN proliferation. Participants learn how they, in their professional capacity or as individuals, must build situational awareness and contribute to raising awareness, education, and outreach within their professional contexts. Such contribution can come in many forms, including the design of such activities, the promotion of ethical standards and professional codes, or the actual running of such activities. Moreover, it emphasizes the value of fostering networks between government agencies and stakeholder communities, as well as among various stakeholder groups.

The seminar modules

The three proposed seminar modules create the space for applying active learning methods through exercises and case studies relating to the topics covered in the introductory and substantive modules. While envisaged as self-contained units to promote student assimilation of the theoretical and conceptual parts, the lecturer has significant leeway over integrating the practical lectures.
The course outline proposed the following themes for the seminars:

- *SE1* reinforces the objectives of SM1 and SM2. It could engage students in two ways. First, they can relate to the issues they believe affect them most and identify the actors with whom they should interact to prevent proliferation. Through group discussions, they can explore how similar issues present themselves to different actors and discover whether another person's insights and experiences may be relevant to one's context. Second, students can be familiarized with particular national and international tools (such as internet resources).
- In *SE2* (suggested to follow SM3), course participants could be presented with specific scenarios they must resolve using the national regulatory frameworks and institutions. Discussions could, for instance, lead to identifying gaps or opportunities for amelioration, thus leading to policy options and their justification.
- *SE3* (suggested to follow SM4) can combine two objectives. First, students can be exposed to (experience) various educational strategies and acquire practical insights into their design and goals. A second part of the seminar can be dedicated to the interactive review of the whole course and preparation of the dissertation, etc.

As noted earlier, the need for a multi- and cross-disciplinary approach in education was one of the crucial findings in the ABEO report of February

2018. The organization of the modules reflected this need. The TSNU integrated the two introductory and four substantive modules in a two-year master's program called "Economic Security of Entrepreneurship". Guest professors taught the modules for the first time. Their primary areas of expertise were CBRN armament and disarmament dynamics (IM1 and SM1), international law and export controls (IM2 and SM2), domestic implementation of international legal obligations (SM3), and governance of science and technology (SM4). Besides the students, the local professors slated to take over the modules in the next academic year also followed the lectures. Among them were economists, political scientists, legal experts, and nuclear physicists. This combination of guest professors and aspiring local academic staff highlighted the multi-disciplinary mix of a course on transfers involving CBRN-relevant dual-use technologies.

In February 2021, the Technical University of Moldova organized a one-week intensive course on non-proliferation education (repeated in 2022). Local professors had expertise in nuclear physics and technology transfers but also wanted to enhance their knowledge about issues and challenges in the chemical and biological fields. However, student participants reflected the rich disciplinary diversity the course attracted. Technical University of Moldova master's students from the Schools of Micro-nanoelectronics and Biomedical Engineering and fourth-year undergraduate students from the School of Biomedical Engineering attended the lectures. In addition to the students mentioned above from the Technical University of Moldova, master students from various universities were also in attendance, including participants from the State University of Moldova (law and physics) and the University of Medicine and Pharmacy (general medicine).[16] The Caucasus International University in Tbilisi, Georgia, inserted elements from the different modules in an existing master's course on international security and non-proliferation and appointed the TI's overall coordinator as a visiting professor.[17]

The table below summarizes the main disciplines and issue areas relevant to CBRN-relevant dual-use technology transfers.

[16] J. P. Zanders, "Education on CBRN-relevant dual-use technology transfers in Moldova", The Trench Blog, February 12, 2021, https://www.the- trench.org/education-on-cbrn-relevant-dual-use-technology-transfers-in-moldova.

[17] Dr Maria Espona (Argentina) was the appointed overall coordinator of the Targeted Initiative.

Multi- and interdisciplinary design
(Main subject areas involved)

Law	***Economics***
– International law	– Trade
– Business law	– Entrepreneurship
– Administrative law	– Risk analysis
– Law enforcement and criminology	– Standards
Political and social sciences	***Sciences and engineering***
– Norm development	– Chemistry
– Ethics	– Life sciences
– Social developments	– Nuclear physics
– Security studies	– Risk management
– Government administration	***Etc.***
– Decision-making processes	

Considering that not all faculties or even academic institutions have all relevant expertise in-house, educational and professional networks may offer the simplest and most cost-effective solution to building a well-rounded program supporting disarmament and non-proliferation.

Building networks for sustainability

As noted, sustainability and local ownership are two critical goals of the Targeted Initiatives' master's course on export controls. Since 2019, the master's course has been deployed in various configurations, including intensive short courses (up to one week) and executive courses (two weeks) for students, professors, and professionals. Moreover, the six introductory substantive modules also got integrated into a two-year master's program in Ukraine, and participating institutions in the other target countries also adopted two or more of the modules in existing master's programs depending on specific needs. Finally, the TSNU in Kyiv transferred the course to a different academic unit in the university, allowing the teaching of the introductory modules already in the final bachelor's year. The flexibility in the modular design of the master's

course contributed to the twin goals of sustainability and ownership. Throughout the process, two aspects of sustainability emerged: (a) increasing advanced knowledge capacity among professors involved in the projects and (b) building multi- and interdisciplinary networks among professors across different faculties within a single university, among different universities within the same country, and potentially among universities across different countries participating in the Targeted Initiatives. This evolution generated new requirements and challenges to be addressed.

For instance, the Targeted Initiatives allowed the training of professors on both introductory and advanced levels. However, given the intensity of these courses, the training was limited to a select number of professors because of the cost of organizing local or regional in-person sessions or the constraints of virtual teaching. The COVID crisis and the war in Ukraine also restricted the options. Nonetheless, these resource limitations, coupled with unforeseeable events, pointed to the broader risk of losing resource investment whenever teaching staff move to different positions, institutions, or countries. Additionally, factors like employee attrition (e.g. retirement) could further affect the long-term viability of export control education.

Networks inside and among universities, research institutes, and professional organizations can vest institutional interest in the educational project. Similarly, setting up a research base involving multiple stakeholders will support the teaching component by producing graduates who can compensate for attrition over the longer term or help expand the educational and research program. Eventual participation in international networks may contribute to international recognition of expertise in the target countries and lead to invitations to participate in multinational research programs.

Contrary to the master's program, the Targeted Initiatives did not lay out a concrete networking work program because local project partners are responsible for building local ownership and sustainability. It became necessary that one or more of the local project partners assumed the role of social entrepreneur to seek out and nurture relationships with stakeholder communities and other academic and research institutions. To assist the process, the present author developed a note outlining a common framework for local project partners to discuss collaboration and establish a shared research platform dedicated to CBRN-relevant dual-use technology transfer controls.[18] This research platform will

[18] J. P. Zanders, "Multi-disciplinary research in export controls: Supporting long-term sustainability of the ISTC and STCU Targeted Initiatives", Note prepared for the ISTC and STCU, and Targeted Initiatives project partners, (2022). (Last revision: 11 May).

stimulate further thinking by initiative takers in different institutions about possible goals and implementation stages for national or international collaboration. Given the master's course's inter- and multi-disciplinary foundation, the shared framework also facilitates the identification of potential partners in different subject fields.

Different development stages

The above-mentioned note outlining a common framework for local project partners identified five development stages: (a) program preparation, (b) program support, (c) setting future priorities, (d) looking for the sustainability of the course, and (e) expanding research and teaching capacities.

Interest in setting up an educational program on CBRN-relevant dual-use technology transfer controls will most likely originate with a small group of advocates, most likely professors or academics, perhaps within a single faculty, possibly as an inter-faculty initiative. The initiative takers will face several questions they must address as a matter of priority in this early stage. Therefore, the first stage of program preparation is articulating the core goals and strategic planning, identifying (learning?) needs, and mobilizing resources. The initiative takers must, therefore, clearly understand initial needs, types of required knowledge and levels of issue awareness, and strategies to engender interest among key decision-making actors and potential target audiences. In constructing their arguments and designing strategies for a successful launch, they also need to consider the circumstances in which their target audiences function. This awareness includes a clear vision of their specific sectorial needs and insights into prevailing levels of awareness about the dual-use potential of their activities.

Whereas the first stage focuses on the general purpose of the master's program, *program support* deals with more detailed planning issues concerning the course set-up that the initiative takers will have to address when facing university decision-makers, government officials (e.g. certifying the program and recognizing degrees), or potential funders. Attracting students will be a primary goal, and having clear and concrete answers available is the bedrock of a promotional campaign targeting the decision-makers mentioned above. The second stage requires balancing ambition and vision with what is feasible from a political, administrative, and resource angle in the present and near future. Furthermore, it involves an idea of how the initiative may evolve over the next few years and a realistic appreciation of risks to the project and ways to avoid, overcome, or mitigate such risks. Questions the initiative takers need to address include clear identification of needs among potential target audiences,

including students, government agencies, and relevant economic sectors. They will have to consider whether all the necessary subject competencies are available in their group or whether they will need to approach additional professors. Finally, early funding questions need concrete answers, and if required, they must be able to identify funding sources.

The third stage, *setting future priorities*, is also the final preparatory phase, but the course development will likely continue to be refined after its initiation. While the persons involved in setting up a new educational program can reasonably be expected to have a good grasp and overview of the subject matter, they may still benefit from a comprehensive issue-mapping exercise. Those benefits may support arguments to set up the program and provide insights into course planning, work organization, and task distribution. They may also identify linkages to other areas or disciplines supporting multi- and interdisciplinary research and teaching approaches. The initiative takers will also design and begin implementing the educational modules at this stage.

The next two developmental stages aim to consolidate and sustain the master's course. The *sustainability of the course* will depend on several material factors, notably reliable student intake and funding stability. However, making the course viable over a longer period requires investment in immaterial future capacities. It implies investment in reputation among students, peers, and funders. One key aspect to consider in this fourth phase is building and maintaining future capacities. The initiative takers must ensure a sufficient influx of new staff with relevant teaching and research competencies. These can be obtained through external recruitment or the formation of highly qualified graduates at the master's and PhD levels. Both pathways depend on establishing a highly regarded reputation and course legitimacy. Building networks within their institution and involving experts from other national and international universities and stakeholder communities are essential for these goals. As noted above, having a network available also obviates the need to consolidate all expertise in a single institution. The initiative takers can draw on external competencies for specific tasks.

The fifth and final stage concerns *expanding research and teaching capacities* over time. To this end and to ensure continuous development, it is necessary to have a longer-term vision of the educational program and to establish milestones for the teaching and research staff to achieve within well-defined time frames. In addition to specific formal criteria, those milestones should also consider the different preconditions for sustainability. These goals are geared towards forming high-quality graduates and high-level academic and applied research output to support export control policies and their implementation. Their sustained

achievement will likely retain the interest and support of decision-makers, funders, and students.

Enabling factors in each development stage

This networking framework does not represent an obligatory or recommended pathway but instead lays out multiple factors for initiative takers to consider. Therefore, each stage is organized along three sets of factors—*needs*, *knowledge*, and *visibility*—whose consideration and fulfillment may contribute to ensuring and consolidating progress.

- *Needs* comprise the prior requirements to undertake a particular activity or enable moving to the next stage.
- *Knowledge* is critical to establishing the research and educational pillars of the master's program and the functioning and sustainability of the research base. Knowledge entails:
  - awareness about the different issues areas relating to CBRN-relevant dual-use technology transfer controls;
  - the ability to identify future educational and research needs and set future priorities;
  - support for the education and research needs of students; and
  - continuous expansion of academic competencies.
- *Visibility* plays a vital role in the sustainability of the educational and research goals because it enables interactions with key stakeholder communities, including
  - outreach to students to encourage them to enroll in the academic program;
  - outreach to decision-makers in faculties, university or research institutions, and government agencies who have a bearing on the authorization, recognition or accreditation of the educational and research program;
  - outreach to industry, professional organizations, and research institutions to broaden the relevancy of the academic and research program (including for promoting a culture of responsibility to prevent proliferation risks, to have them adopt policy recommendations, or for obtaining traineeship positions for students, among other things);
  - building credibility among international organizations, foundations, and other agencies granting funds for research and other relevant projects; and
  - integration and participation in international networks and consortiums.

The five stages and their respective sets of factors apply to local capacity development and establishing a multi- and interdisciplinary education and research network in a country or region. Each subsequent stage builds on earlier achievements.

A flowchart with options for consideration

The five stages and the three sets of factors for each stage make for a complex flowchart that takes up several pages. Figure 2 illustrates Stage 4 focusing on the long-term sustainability of the master's course. Central elements are knowledge production and organizational resilience, in the function of which, for example, student graduations and personnel attrition are important considerations. Furthermore, the figure illustrates how the outputs of one stage serve as inputs for the subsequent step, facilitating progression toward the fifth and final stage.

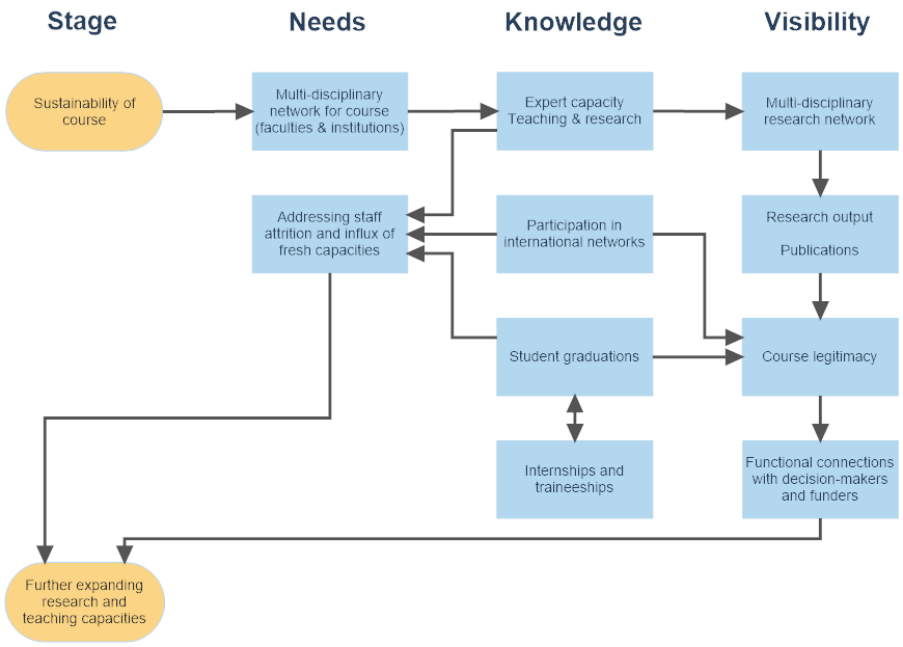

Figure 2 EU TI (master) research network: Stage 4 requirements

The flowchart may serve some secondary functions, too. For instance, when preparing funding proposals, it can aid in identifying concrete project goals, potential risks, and ways to mitigate them. Most importantly, with the flowchart, the project proposers can put forward doable timelines for specific project elements and describe clearly how these will contribute to the ultimate goals. The same applies to project reporting. The flowchart can be a checklist to mark achievements or issues requiring further work.

When building networks, the potential partners can also use the flowchart to determine the types of capacities they may contribute to the joint endeavor and which ones they may have to develop to become full participants. Institutions with specific capacities useful for more advanced stages may thus be able to assist universities in setting up an export control educational program.

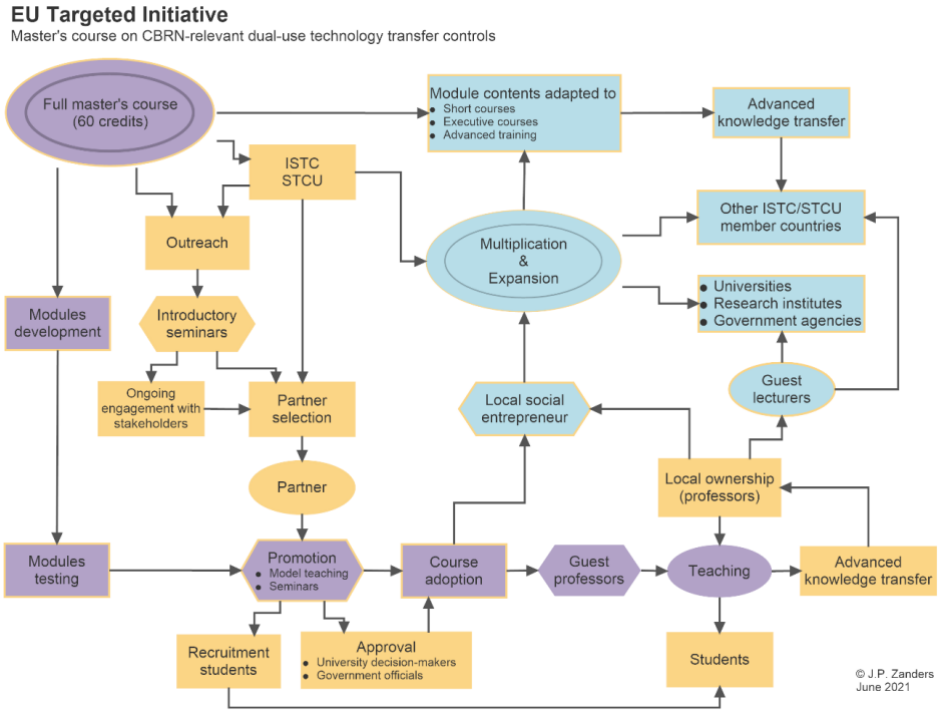

Figure 3 Summary of the processes in the setting up of the master's course. Legend : purple: setting up the course; yellow: engaging with decision-makers and stakeholder communities; blue: network building

A preliminary assessment of the Targeted Initiatives

The Targeted Initiatives ended on December 31, 2023, six years after its launch. The present paper was written during the final months of its implementation, making it challenging to fully assess the impact of the education work package. Despite this difficulty, some tangible outcomes can be noted. For instance, in all participating Central Asian and GUAM countries, the respective educational authorities accredited the master's courses on CBRN-relevant dual-use technology transfers incorporating two or more modules prepared under the Targeted Initiatives. Moreover, students have graduated and found employment in the field of their studies. Perhaps most significantly, teaching activities and program

expansions in the partnering academic institutions continued despite the COVID-19 pandemic and, especially in Ukraine, the war.

In addition to the design of the master's course, sustainability, local ownership, and network-building were key objectives. Assessing the long-term impact of the Targeted Initiatives is necessarily a future activity. A first detailed evaluation of all work packages within the initiatives, along with recommendations for future projects, should be ready by August 2024. Despite this pending evaluation, the overall impression is positive. Course accreditation and student graduations reduce institutional resistance and motivate the continuation of the activities. Furthermore, the engagement with stakeholder communities and key decision-makers in academia, research institutions, government agencies, and the private sector has created a growing demand for expertise in CBRN-relevant dual-use technology transfer.

Travel restrictions imposed during and in the aftermath of the COVID-19 pandemic, as well as the war in Ukraine, hobbled the in-person dimension of networking. Yet, adopting virtual educational methodologies and online meetings offered unique opportunities to expand engagement with new partners across much larger geographic areas. Online lectures welcomed students from different academic institutions, fostering broader participation and collaboration. Additionally, outreach activities and seminars attracted the interest of high-level decision-makers across multiple universities and research institutions, thereby broadening the understanding of the importance and necessity of the technology transfer educational program.

The networking efforts continue in 2024. For example, the Caucasus International University in Tbilisi is preparing an edited volume on dual-use technology export controls with financing from the Targeted Initiatives via the STCU. Notably, the authors are local project partners from Central Asia and the GUAM countries. Reflecting on the organization of their educational activities, the local needs, and future plans, two authors from Kazakhstan have summarized their work over the past years as follows:

> "In collaboration with QazTrade and QazIndustry, two quasi-state companies facilitating manufacturing industries and export from Kazakhstan, the project successfully enabled the Eurasian National University (in 2021), Maqsut Narikbayev KAZGUU University (in 2022), Satbayev University (in 2022), Suleyman Demirel University (in 2023), and Kazakh-British Technical University (in 2023) in launching the majors and minors education programmes in Strategic Trade Control.
> The project team members promoted research collaboration with the European Studies Unit at the University of Liege, Belgium and the

> Center for International Trade Security at the University of Georgia, Athens, USA. [The Central Asian Institute for Development Studies (CAIDS)] also encouraged networking with universities in former Soviet countries,[19] such as the Kyrgyz State University in Bishkek, Kyrgyzstan, and Kyiv University, Ukraine, with a perspective agenda.
> The long-run sustainability of applied research and education programs is to be attained through (a) increasing advanced knowledge capacity among professors involved in the projects and (b) building multi- and interdisciplinary networks among professors and experts from different faculties in a single university or from different local universities, and, if possible, from universities of other countries participating in the project.
> These national measures reflect Kazakhstan's commitment to addressing CBRN threats and ensuring the safety and security of its citizens and the broader region. It is important to note that CBRN security is a complex and ongoing challenge that requires continuous monitoring, adaptation, and international cooperation."[20]

The involvement of trade and industry associations, along with the initiation of courses at multiple academic institutions (in this example, in Astana and the Almaty Province), shows the broad recognition of the need for education and engagement in technology transfer controls after sustained investment in outreach. This testimony illustrates the difference between education and training or capacity-building.

Conclusions

The article underscores the imperative for sustainable efforts in building a culture of responsibility among stakeholders in the target countries, particularly concerning dual-use technology transfers. While many vocational training programs and projects in treaty implementation assistance or norm-strengthening initiatives often falter due to their one-off nature or reliance on external funding, the master's course, as part of the Targeted Initiatives, sought to buck this trend.

Central to this ambition is the recognition that mere knowledge transfer will always remain insufficient to shape attitudes. Instead, the master's course adopted a comprehensive educational approach aimed at

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[19] See International Business and Strategic Trade Control, CAIDS, https://caids.kz/sec/stc.html.

[20] K. Moldashev, and G. Makhmejanov, "Regional threats posed by CBRN weapons and their underlying technologies and corresponding measures taken in a regional context", in J. P. Zanders, and M. Espona, eds., (2024, Forthcoming). *Transfer Controls and the Prevention of the Proliferation of CBRN-Relevant Dual-Use Technologies*, Tbilisi, Caucasus International University.

enhancing awareness and fostering responsible behavior among audiences. This approach entails not only imparting knowledge but also empowering individuals to identify and assess short-term and longer-term risks and threats, and acquire situational awareness to maintain standards of responsible behavior.

To fulfill this ambition, the article suggests that institutions in the target countries—universities, research institutes, and other entities dealing with dual-use technology transfers—must become invested in the process. Furthermore, it outlines a three-pronged strategy to advance this goal. First, it emphasizes an educational methodology that places the target audience at the center, ensuring their active engagement in the learning process. Second, it highlights the importance of outreach to key university decision-makers—rectors, faculty deans, and members of educational boards—to persuade them of the need to incorporate education in dual-use technology risk management in the curricula—and to key stakeholders in science, industry, and government agencies. Additionally, the paper underscores the significance of investing in the advanced teaching of professors in the subject matter and assisting in establishing a research base to further academic expertise in the field.

Furthermore, the article emphasizes the importance of supporting and encouraging local initiatives aimed at building academic and professional networks, both nationally and internationally. These latter aspects not only have significant educational value in their own right but also contribute to fostering local ownership and ensuring sustainability.

International and national rules on technology transfers appear negative to most key stakeholders. They may constrain research, limit publishing research findings, or impose costs and administrative burdens on industry, trade, and research. Most importantly, they may perceive the constraints as especially burdensome because they do not view themselves as involved in any activity that might contribute to CBRN weapons.

Education, in contrast, serves as a positive means of engaging relevant scientific, academic, and professional communities. It makes them aware of certain risks related to their work; it encourages them to consider options that reduce or eliminate such risks, to act if they become aware of such risks, and, more generally, it helps them to preserve the legitimacy of their activities.

Moreover, education offers the advantage of introducing people to risks and threats early in their careers and providing ongoing updates to adapt to evolving settings. Thus, education goes beyond training, the primary objective of which is to augment specific skill sets and expertise to

increase task performance. Indeed, education contributes to the establishment and maintenance of a general academic, scientific and professional culture of responsibility that not only affects the daily behavior of individuals, institutions, companies, and government agencies but also creates a shared space for cooperation among all to prevent deliberate or inadvertent technology transfers that could contribute to illicit CBRN weapon acquisition by foreign states or non-state actors.

In conclusion, the master's course, along with the broader efforts of the Targeted Initiatives, represents significant steps towards building a culture of responsibility in the realm of dual-use technology transfers. Through sustained educational efforts and collaborative initiatives, stakeholders can work together to address the challenges posed by such transfers and contribute to global security and non-proliferation efforts.

Acknowledgments

This paper reflects the author's involvement in setting up the master's program as part of the Targeted Initiatives and the evolution of his thinking. However, the outcomes would not have been possible without the brainstorming sessions, comments, and suggestions of the Targeted Initiative partners over the six-year running period. They include Dr Maria Espona (Argentina), the overall project coordinator, as well as contributions from the work package leaders, Ms Anne Harrington (USA), Dr Richard Guthrie (UK), Dr Kai Ilchmann (Germany), and Prof Dr Quentin Michel (Belgium). The exchanges with academic colleagues in Ukraine and Kazakhstan in setting up the courses were also of great value. Other meaningful experiences and insights came from interacting with interested parties in the Kyrgyz Republic, Tajikistan, Georgia, and Moldova. The same goes for the staff at the ISTC and STCU. I refrain from citing their names or identifying their roles because of the war in Ukraine (and ensure equal recognition of all colleagues).

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VIEWPOINT

The role of education in nuclear security compliance: the International Nuclear Security Education Network as a good practice

Şebnem Udum[*]

Abstract

This viewpoint emphasizes the critical role of education in nuclear security compliance, particularly in response to evolving security dynamics post-September 11 attacks. Amidst threats to nuclear and radiological materials in use, storage and transport, the international community has established numerous legal and political instruments mandating national implementation, thereby necessitating state compliance. Domestic institutions are pivotal in this process by enacting legislation and regulations, subsequently implemented by stakeholders. In this context, education is key to accelerating the development of nuclear security culture, especially in the case of newcomer countries, and ensuring the sustainability of national efforts. The viewpoint argues that the International Nuclear Security Education Network (INSEN), operating under the auspices of the International Atomic Energy Agency, serves as a vital platform bringing together researchers and educators in the field of nuclear security. The network facilitates the dissemination of educational programs, modules, and faculty development initiatives, thereby advancing nuclear security education on a global scale. This piece presents INSEN as a model of good practice that has significantly contributed to enhancing state compliance in nuclear security.

Keywords

Education, IAEA, INSEN, nuclear security, state compliance.

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Commentary info

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Introduction

The events of September 11, 2001, highlighted the potential for terrorists to obtain weapons of mass destruction, either from inadequately secured facilities or with assistance from state and non-state actors.[1] Existing frameworks or agreements were aligned in a way that they can address these new threats or new ones were introduced.[2]

Attacks to nuclear facilities, including nuclear power plants, medical facilities and research centers, are potential targets for sabotage, theft, or unauthorized access to steal or tamper with nuclear and/or radioactive material. Critical infrastructure, such as energy generation facilities and land and maritime transportation, can also be targeted by terrorists aiming to disperse radioactive material and disrupt international trade of strategic goods.

Terrorist groups may seek to acquire nuclear material, such as highly-enriched uranium or plutonium, to create improvised nuclear devices. Alternatively, they may attempt radiological terrorism by detonating a radiological dispersal device, also known as a "dirty bomb", using acquired nuclear or radiological material, or a radiological exposure device.[3] Incidents of unauthorized possession or criminal activities involving radioactive materials have been reported to the International Atomic Energy Agency (IAEA) Incident and Trafficking Database. The number of such incidents reached its peak around 2000 and remained steadily high during the first decade of the 21st century.[4]

Sabotage scenarios include physical or cyber-attacks that can result in reactor meltdown and radiation release, or one of a "nuclear 9/11" scenario involving an aircraft crash onto the plant's reactor core, spent fuel storage pool, a nuclear fuel fabrication plant, spent fuel storage facility, or waste repository.[5] Nuclear material in liquid form, such as

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[1] Rolf Mowatt-Larssen, *Al Qaeda Weapons of Mass Destruction Threat: Hype or Reality?,* Belfer Center for Science and International Affairs, Harvard Kennedy School, Cambridge, January 2010.

[2] The 2005 Protocol of the Convention for the Suppression of Unlawful Acts Against the Safety of Fixed Platforms Located on the Continental Shelf (SUA), LEG/CONF.15/22, International Maritime Organization, November 1, 2005; United Nations, International Convention for the Suppression of Acts of Nuclear Terrorism, 2005.

[3] Charles D. Ferguson and William C. Potter, *The Four Faces of Nuclear Terrorism* (Monterey, CA: Monterey Institute of International Studies, 2004), p. 3.

[4] IAEA, "IAEA Incident and Trafficking Database (ITDB)", 2023 Fact Sheet, https://www.iaea.org/sites/default/files/22/01/itdb-factsheet.pdf

[5] See George Bunn et al., "Research Reactor Vulnerability to Sabotage by Terrorists," *Science and Global Security* 11, no. 2-3 (2003), pp. 85-107.

plutonium in a reprocessing plant, is particularly susceptible to theft and sabotage.

Transportation vehicles—cars, trucks and ships—carrying nuclear and radiological material are vulnerable to interception or to infiltration. Ensuring the security of these materials during transportation is a crucial element of nuclear security. Shipping containers may be especially vulnerable to infiltration in ports, where terrorists may place and detonate nuclear or radioactive material in the container and detonate it close to a mega-port or in a maritime chokepoint to cause contamination, hence disruption of maritime transportation and trade of especially strategic goods, affecting the global economy.[6]

Insider threats also pose significant risks, as disgruntled nuclear facility employees or those in charge of transportation vehicle(s) may collaborate with criminals, steal and sell the material, or provide critical information to terrorists.[7] Cyber threats from hackers seeking economic gain may attack nuclear facilities to cause a nuclear safety incident.

Additionally, activists opposed to nuclear power may exploit security loopholes in power plants to undermine the credibility of the state or energy companies regarding nuclear safety and security.

In response to all these threats, existing frameworks and agreements in the field of nuclear security were adjusted, and new measures were introduced to address these emerging challenges.[8] An example of the former, is the 2005 amendment to the Convention on the Physical Protection of Nuclear Material (CPPNM), which expanded its scope to include nuclear material in use and storage, in addition to during transport.[9]

The IAEA defines 'nuclear security' as "[t]he prevention and detection of, and response to theft, sabotage, unauthorized access, illegal transfer or other malicious acts involving nuclear material, other radioactive

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[6] See Paul W. Parfomak and John Fritelli, *Maritime Security: Potential Terrorist Attacks and Protection Priorities*, Congressional Research Service Report for Congress, May 14, 2007,
https://digital.library.unt.edu/ark:/67531/metadc462262/m1/1/high_res_d/RL33787_2007May14.pdf

[7] "Preventive and Protective Measures Against Insider Threats", IAEA Nuclear Security Series, 8-G (Rev.1), (2020), pp. 3-6.

[8] The 2005 Protocol of the Convention for the Suppression of Unlawful Acts Against the Safety of Fixed Platforms Located on the Continental Shelf (SUA); International Convention for the Suppression of Acts of Nuclear Terrorism, UN.

[9] Amendment to the Convention on the Physical Protection of Nuclear Material, INFCIRC/274/Rev.1/Mod. 1 (Corrected), IAEA, October 18, 2021.

substances or their associated facilities."[10] The international regime on nuclear security is underpinned by several legally and non-legally binding international legal instruments, including UN Security Council Resolutions 1373[11] and 1540,[12] the CPPNM-A, the International Convention on the Suppression of the Acts of Nuclear Terrorism, and the Convention for the Suppression of Unlawful Acts against the Safety of Maritime Navigation (1988 SUA Convention) and its 2005 Protocol, IAEA's Nuclear Security Recommendations on Nuclear and Other Radioactive Material Out of Regulatory Control. A regime is formed not only of international law, but also international organizations, agreements, initiatives and even significant individuals.

Although the IAEA was established first and foremost to implement nuclear safeguards to ensure peaceful use, it is also an essential piece of the international nuclear security regime as well. It supports member states in implementing nuclear security related tasks and the Amended CPPNM by a number of means. One primary method is the International Physical Protection Advisory Service (IPPAS) missions, which offer advice and guidance on protecting nuclear and radioactive material, their associated facilities and associated activities. Additionally, the IAEA also assists states to strengthen their national nuclear security regimes by exchanging experience and good international practices in addition to reviewing their security measures during the use and transport or nuclear and radioactive material upon state request.[13] Another significant support method is funding Coordinated Research Projects related to the security of nuclear and radioactive material.[14] The Agency also issues a Nuclear Security Plan based on member states' priorities for their nuclear security activities.[15] Although establishing national nuclear security regimes was a task that dates back to 1970s, September 11 was *the* turning point for the IAEA. In March 2002, the IAEA Board of Governors approved the first comprehensive plan of action to protect against nuclear terrorism, along

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[10] IAEA, "IAEA Nuclear Security Glossary", August 2020, p. 22, https://www.iaea.org/sites/default/files/21/06/nuclear_security_glossary_august_2020.pdf

[11] United Nations Security Council Resolution 1373 (2001), September 28, 2001, S/RES/1373 (2001).

[12] United Nations Security Council Resolution 1540 (2004), April 28, 2004, S/RES/1540 (2004).

[13] International Physical Protection Advisory Service (IPPAS), IAEA, accessed April 19, 2024, https://www.iaea.org/services/review-missions/international-physical-protection-advisory-service-ippas

[14] "Coordinated Research Projects – Security of nuclear and other radioactive material", IAEA, accessed April 21, 2024, https://www.iaea.org/projects/coordinated-research-projects?type=3720&status=5017&topics=3105

[15] Nuclear Security Plan, IAEA, April 21, 2024, https://www.iaea.org/topics/security-of-nuclear-and-other-radioactive-material/nuclear-security-plan

with the Nuclear Security Fund—a voluntary funding mechanism to help implement the Plan.[16]

Another component of the nuclear security regime is the Global Initiative on Combatting Nuclear Terrorism, formed by the United States and Russia in 2006 during the G-8 Summit in Russia. This initiative builds on the CPPNM-A and UN Security Council Resolutions (UNSCRs) 1373 and 1540.[17] Following former US President Barack Obama's 2009 speech in Prague—which underlined nuclear and radiological terrorism as the most important threats to security[18]—Nuclear Security Summits were convened starting from 2010 at head-of-state level to raise awareness and get international support for proposed actions.

In addition to these initiatives, the International Nuclear Security Education Network (INSEN) was established in 2010. [19] It is another vital component of the regime; it promotes education and training in nuclear security, essential for maintaining national nuclear security regimes and ensuring compliance within the international framework. The role and contributions of INSEN will be further discussed below.

The nature of the threat necessitates that responses be developed and strengthened at the national level, ultimately constituting state compliance. A national nuclear security regime includes legislation, regulation, intelligence, assessment of the threat to radioactive material and associated locations and facilities, administrative and technical systems, response capabilities and mitigation activities. Operational procedures must be clearly defined and diligently followed by those in charge. Therefore, effective functioning of the nuclear security regime depends on the people involved, including operators and managers. Public awareness and stakeholder cooperation are crucial in ensuring nuclear security, making the development of a robust nuclear security culture essential.

To enhance the existing nuclear security culture, the human factor must be addressed. To that end, the IAEA endorses a pyramid-like structure for the development of this culture. The foundation is formed by beliefs and

[16] Nuclear Security Plan, IAEA.
[17] Global Initiative to Combat Nuclear Terrorism (GICNT), Nuclear Threat Initiative, accessed April 21, 2024, https://www.nti.org/education-center/treaties-and-regimes/global-initiative-combat-nuclear-terrorism-gicnt/
[18] Remarks by President Barack Obama in Prague as delivered, The White House, April 5, 2009, accessed March 25, 2023, https://obamawhitehouse.archives.gov/the-press-office/remarks-president-barack-obama-prague-delivered
[19] The International Nuclear Security Education Network, IAEA, accessed June 20, 2024, https://www.iaea.org/services/networks/insen

attitudes of actors, based on two main assumptions: first, that credible threat exists, and second, that nuclear security is important. Only with these assumptions in place can principles be developed, which are (a) motivation, (b) leadership, (c) commitment and responsibility, (d) professionalism and competence, and (e) learning and improvement. These principles then lead to well-developed management systems that prioritize security and behaviors that foster more effective nuclear security.[20] Thus, such effectiveness "[…] depends upon the extent to which these beliefs and attitudes are commonly held and manifest themselves in appropriate behavior and practices."[21] Nuclear security should be a concern not only to the facility personnel but also to the public.[22]

The IAEA technical guidance on nuclear security culture self-assessment envisions a 'universal' nuclear security culture as the ultimate goal for all states.[23] However, the definition and perception of threat can vary from state to state, and security and safety cultures may differ. Consequently, international instruments and plans of action for response may prove to be insufficient. Thus, 'compliance' in nuclear security cannot be ensured solely through international efforts; it requires cooperation among all national stakeholders. This involves developing a common belief of the threat, being informed about the actions to take at each stage of the nuclear security plan, and, most importantly, cultivating a nuclear security culture.

States with previous exposure to nuclear technology and operational challenges of nuclear facilities are likely to have already developed such a culture. However, this presents a challenge particularly for newcomer countries in the nuclear industry. The nuclear energy élite—comprising bureaucracy, academics and technical personnel in the industry—are typically well-informed, but other stakeholders require professional training and education to bridge the gap.

Education and training in nuclear security, however, are often understudied topics for the development, maintenance and strengthening of both national and international efforts to counter threats to nuclear and radiological materials, whether from state or non-state actors. This viewpoint piece emphasizes the vital role of education and training in ensuring nuclear security. Specifically, it sheds light on the INSEN as a professional network of nuclear security educators and researchers, and

[20] Nuclear Security Culture, IAEA Nuclear Security Series, No.7, IAEA, 2008, p.18.
[21] Nuclear Security Culture, IAEA, pp.4, 19.
[22] Nuclear Security Culture, IAEA, p.20.
[23] Self-assessment of Nuclear Security Culture in Facilities and Activities, IAEA Nuclear Security Series No. 28-T, IAEA (2017), 3, https://www-pub.iaea.org/MTCD/Publications/PDF/PUB1761_web.pdf

their activities contributing to raising awareness and human resource development. It is another vital component of the regime; it promotes education and training in nuclear security, essential for maintaining national nuclear security regimes and ensuring compliance within the international framework. It is essentially a platform (for nuclear professionals or states) to exchange experiences. The role and contributions of INSEN will be further discussed below in more detail. Education and training in nuclear security are essential for the maintenance of national nuclear security regimes, which is part of compliance within the international nuclear security regime.

National nuclear security regime and education

An international regime is established upon principles that serve as the foundation for rules, decision-making procedures, and norms on a specific issue, around which states align their national interests.[24] States are expected to develop national nuclear security regimes to fortify the international regime—as outlined in the UNSCR 1540[25]—and particularly emphasized as a fundamental goal in the CPPNM-A.[26] UNSCR 1540 and the Amended Convention mandate that states adopt domestic legislation and foster stakeholder cooperation in developing a national nuclear security regime.

The underlying assumption is that individual country efforts and compliance will maintain and strengthen the international regime. The IAEA's 2020 Nuclear Security Conference highlighted the importance of "identification of national needs through the development of an Integrated Nuclear Security Support Plan", with participants focusing on its benefits, such as applying a comprehensive approach to strengthening their nuclear security regimes. This is essential for enhancing coordination among relevant competent authorities.[27]

The international regime on nuclear security is only "as strong as the weakest link in the chain."[28] This is because the threat is assumed to originate from non-state actors, necessitating action at the domestic level

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[24] Stephen D. Krasner, "Structural Causes and Regime Consequences: Regimes as Intervening Variables," *International Organization*, Vol. 36, No. 2, Spring 1982, p. 186.
[25] United Nations Security Council Resolution 1540, S/RES/1540 (2004), April 28, 2004.
[26] Amendment to the Convention on the Physical Protection of Nuclear Material.
[27] "International Conference on Nuclear Security: Sustaining and Strengthening Efforts", IAEA,
Vienna, Austria, February 10-14, 2020, p. 27.
[28] "NTI Nuclear Materials Security Index: Building a Framework for Assurance, Accountability and Action", the Nuclear Threat Initiative, January 2012, p.3.

as required by the amended Convention. The nuclear security regime adopts a 'bottom-up' approach. Ensuring nuclear security involves prevention, detection and response stages,[29] which require coordination among various departments and agencies within a state, including the regulatory authority, facility operators, ministries of energy, interior, health, transportation, national defense, departments of security and law enforcement, coast guard, intelligence agencies, media, and local communities.

Accordingly, states are expected to establish relevant divisions, enact and implement laws, develop a nuclear security culture, and cultivate human resources. Awareness and an accurate assessment of the threat are necessary for the sustainability of national nuclear security regimes. Merely having laws and regulations in place does not guarantee successful implementation. Often, achieving nuclear security goals across different agencies and institutions poses a challenge. For starters, energy and security bureaucracies need to work together and develop standard operating procedures, pushing beyond their comfort zones to address nuclear security comprehensively. Moreover, nuclear security is unsuited to compartmentalization and requires a basic knowledge of all its facets, including the technical aspects of nuclear energy generation, radiation protection, design basis threat, physical protection, cyber security, threat assessment, forensics and insider threats. That is why, professional training in nuclear security designed for particular stakeholders (agencies/institutions involved in ensuring nuclear security) reinforces this divide and each one will continue to 'speak its own bureaucratic language' when a case arises. To break this vicious circle, either educators/experts on nuclear security should provide such education during professional development or training programs which are particularly designed for a certain profession, or a new generation of nuclear security experts should be raised so that the national nuclear security regime will be sustainable.

Education serves several purposes in the development of national nuclear security regimes. Firstly, it raises and maintains awareness on nuclear security-related threats and challenges. Secondly, it fosters the development of human resources and a new generation of nuclear security experts. Thirdly, it helps embed nuclear security culture within the government, industry and academia.

The amended CPPNM determines the development of nuclear security culture as a fundamental element. More specifically, it requires the development of nuclear security culture at all levels of operation

[29] IAEA Nuclear Security Glossary, IAEA, (August 2020), p. 22.

(managers, operators, and personnel) and its dissemination to stakeholders. The core belief that 'nuclear security is important' must be ingrained within institutions and individuals, facilitated by informed decision-making. Bureaucratic cultures may hinder the assimilation of new information and the roadmap for nuclear security goals. To address this, education and training are essential, particularly in newcomer countries in the nuclear industry where there is a limited number of professionals who are experienced to work in the nuclear energy sector. Education and training orient the stakeholders towards threat assessment, and definition of threat and understanding their responsibilities in the stages of nuclear security (prevention, detection and response), and building a nuclear security culture, thereby fostering proactive rather than reactive behavior by stakeholders in nuclear security-related scenarios. Education in nuclear security also ensures a continuous supply of human resources to serve in civilian and military bureaucracies with a sound understanding of nuclear security principles, contributing to the regime's sustainability. Next section focuses on INSEN as a good practice on the contributions of education.

INSEN as a good practice

Established in 2010, INSEN serves as a link between the IAEA and educational institutions, whereby it contributes with teaching material, curriculum and faculty development, and faculty exchange opportunities through its working groups. The added value of such an international infrastructure to support education efforts is linked with the philosophy of having an international organization to coordinate international efforts for cooperation towards the resolution of a certain issue: in this case, nuclear security. Education is part of these efforts under the nuclear security division aiming to inform and raise awareness in the wider public with accurate information on the threats, scenarios and responses. The network operates through three working groups: Working Group I focuses on curriculum development; Working Group II focuses on faculty development and exchange; Working Group III works on the promotion of nuclear security education and INSEN.

Since its establishment, INSEN's membership has grown significantly. The eligibility criteria are the offering of nuclear security related courses, teaching modules or graduate programs. One of the network's key contributions is that through its working groups and leadership meetings, researchers and scholars of nuclear security have assumed the "identity" of being the "academic piece" of the developing international nuclear

security regime.[30] This makes the network an indispensable part of their academic status both at home and abroad. Thereby, through networking, they also contribute to nuclear security education activities within their respective institutions.

INSEN is significant not only because it helps states at the national level but also because it has a multiplier effect at the international level by bringing together academics and researchers from around the world. The main contribution and impact of INSEN on nuclear security is to raise awareness by equipping and supporting faculty in educating students and professionals. INSEN has been instrumental in facilitating the development and implementation of nuclear security education through several means:

- *Annual meetings and working group sessions:* these are held at the IAEA headquarters in Vienna, where scholars and researchers from INSEN institutions share their programs and progress in teaching nuclear security. This includes degree programs, modules, curricula, and faculty development courses, which serve as a good practice.
- *Teaching materials*: INSEN provides teaching materials developed by subject matter experts, which members can use in their courses.
- *Faculty exchange and development opportunities*: members can organize or develop faculty exchange opportunities or faculty development courses to enhance their expertise and serve with newly acquired knowledge in their particular institutions.

The IAEA has developed the Nuclear Security Series-12 in 2010 and its updated version, NSS 12-T (Rev. 1) Model Academic Curriculum in Nuclear Security, in 2021, to guide educators for developing course content and degree programs.[31]

In the Nuclear Security Series 28-T, the "Self-Assessment of Nuclear Security Culture" assumes that all members should achieve a similar level of nuclear security culture.[32] Therefore, they need to acquire a general knowledge of nuclear security, related scenarios, threats, and actors.

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[30] Şebnem Udum, "INSEN As Part and Propellant of Nuclear Security Regime: An Insider's View," *International Journal of Nuclear Security*, Vol. 6, No. 2 (Special Issue), 2020.
[31] Model Academic Curriculum in Nuclear Security, IAEA Nuclear Security Series No. 12-T (Rev. 1), IAEA, https://www-pub.iaea.org/MTCD/Publications/PDF/PUB1930_web.pdf
[32] Self-assessment of Nuclear Security Culture in Facilities and Activities, IAEA Nuclear Security Series No. 28-T, IAEA (2017), p. 3, https://www-pub.iaea.org/MTCD/Publications/PDF/PUB1761_web.pdf

INSEN member activities, including Professional Development Courses (PDCs), help to achieve this goal. These courses are not just offered in English: to overcome language barriers and focus on regional needs, PDCs were organized in Africa in French and Arabic, and in Latin America in Spanish.

The author has witnessed significant mutual contributions between the members and the network, benefiting individual academics and researchers in their teaching and research. Firstly, INSEN has developed a unique "nuclear security education community". Members maintain constant contact beyond the annual or working group meetings, facilitated by their active participation in working groups and the networking opportunities provided during their time at IAEA headquarters and leisure time in Vienna. This sustained interaction over fourteen years created a sense of 'befriended colleagues', which has facilitated the organization of various activities. Secondly, the lockdowns and the shift to virtual meetings due to the Covid-19 pandemic have increased opportunities for engagement, supplementing the once-in-a-year annual meetings. This transition has enabled members to interact more frequently and effectively. Lastly, the leadership structure of INSEN, characterized by a system of trinity (former, current and vice chairs) and the continuing involvement of former network chairs, ensure the transmission of "network memory and experience" to incoming chairs and vice chairs of working groups, as well as to new members. This continuity supports the development of nuclear security education and the enhancement of national nuclear security regimes.

In the next section, the author will share personal experience of teaching nuclear security, illustrating how INSEN has contributed to the success and development of their instructional methods.

Education and training in nuclear security

Teaching nuclear security is challenging at both national and global levels. Few disciplines receive training in policy and lack a comprehensive understanding of nuclear security risks and threats across technical, political, and international dimensions. Furthermore, the links between academia and government may be weak. Language poses another problem, particularly regarding terminology in local language at the national level. The type of audience also impacts how information is received. Table 1 outlines audience expectations depending on whether the instructor is in a teaching environment or training professionals or professors.

Audience/Properties	**Students**	**Professionals**	**Professors**
Background	Limited	Focused	Academic
Expectation	Jobs	Career development	Progress in teaching
Attention	Limited	Need-based	Forward-looking

Figure 1 Characteristics and expectations of different audiences in nuclear security education

The first group is students who are intelligent but usually uninformed about nuclear security, and their main focus is on securing jobs. Therefore, their attention is limited, as they are still developing their foundational knowledge. The second group is composed of professionals with focused backgrounds, mainly related to their specific roles and are interested in career development and promotion. Their attention is need-based, concentrating on information that is relevant for their job performance and career growth. The final group are professors who are advantaged in having academic backgrounds with a comprehensive understanding of the subject matter. They have a wider understanding of the issue, seek progress in teaching and are forward-looking, often interested in the latest developments and research in the field.

An outstanding issue in teaching nuclear security is the discrepancy between the backgrounds of the educators and students, as nuclear security straddles both natural and social sciences, most notably, physics, nuclear engineering, forensics, political science, international relations, and psychology. INSEN has contributed to the author's academic progress by fostering an interdisciplinary approach. With a background in International Relations and nearly two decades of experience in studying and teaching nuclear non-proliferation, the author is informed about the basics of nuclear technology.

Teaching nuclear security involves four probabilities of instructor/student interaction. Two scenarios occur when the instructor is from a STEM (Science, Technology, Engineering and Mathematics) field and students are from social or technical sciences. The other two scenarios occur when the instructor has a social science background, and students are from either social or technical sciences. Since becoming an INSEN member, the author has taught to both audiences, identifying which allowed her to detect issues that arise when a STEM instructor teaches about nuclear issues to an audience with a social science background.

For compliance training in nuclear security, the audience is not usually students, but typically professionals from different government departments. In this case, the main roadblock is the bureaucratic culture and the people's receptivity to "new information." Each bureaucracy tends to receive (learn) or give attention to the topics they find related or relevant

to their specific department. However, nuclear security is a topic that requires basic information on all facets, including safety and security, so that a nuclear security culture can be developed, hence a sustainable compliance for the particular state.

The instructor should pay attention to the audience and underline the message that the training is not for a certain bureaucracy or department, (such as security or energy, or nuclear safety, nuclear security, physical protection, legal affairs, operations, etc.), but it is an essential part of compliance with international legal commitments of their state. The purpose of the training is to prepare the stakeholders to structure their respective roles as per the stages of nuclear security and strengthen their capabilities. Thus, they need to learn about the basics of nuclear and radiological material, radiation protection, scenarios of theft, sabotage, unauthorized access; means of detection, strengthening security measures, adopting layered defense, how to cope with insider threats and cyber threats, to cooperate with the public in detecting intentions and to respond to incidents. The audience in nuclear security education and training would include most notably students of social science, physics and nuclear engineering, government officials from relevant agencies and departments, and professionals, who will be or are working in nuclear facilities or those including nuclear and radioactive material.

Conclusion

Following September 11 attacks, vulnerability of nuclear and radiological material in use and storage (in facilities) and transport (in vehicles and vessels) to malicious intent raised concerns for their security against scenarios of theft, sabotage or unauthorized access to the material or the facility. An ensuing nuclear safety failure, disruption of land or maritime trade and transportation routes or mass panic and anxiety would create a nuclear and/or radioactive September 11. Hence a new international regime on nuclear security has been developing.

The nature of the threat requires that responses be developed and strengthened at the national level-which constitutes state compliance. The effective functioning of a national nuclear security regime depends not only on facility personnel but also stakeholder harmony that would eventually result in the development of nuclear security culture. The latter is a fundamental element foreseen in the amended CPPNM that upholds the regime.

Education emerges as a linchpin in this endeavor, serving to raise awareness, cultivate expertise, and instill a culture of security across government, industry and the academia. Last but not least, the

development of operational level safety and security culture would contribute to the harmony of stakeholders and their active involvement in nuclear security related tasks. Through INSEN, collaborative efforts among scholars and professionals further amplify the impact of such educational endeavors, fostering a robust community dedicated to advancing nuclear security.

This article focused on INSEN as a good practice for nuclear security education to contribute to the development of national nuclear security regimes. It argued that it had a multiplier effect at the international level by bringing together academics and researchers from around the world. The main contribution and impact of INSEN on nuclear security is to raise awareness through equipping and supporting faculty to educate primarily students but also professionals by developing training materials, designing and implementing courses and curricula, and engaging in advocacy and outreach on the value of promoting nuclear security competence among relevant practitioners.

INSEN has developed a unique 'nuclear security education community'. Throughout the working groups and leadership meetings, researchers and scholars of nuclear security have assumed the "identity" of being the "academic piece" of the developing international nuclear security regime.[33] This makes the network an indispensable part of their academic status at home and abroad. Thereby, by networking, they also contribute to nuclear security education activities in their institutions. In sum, collective engagement enriches individual professional development in the realm of nuclear security. Through concerted educational efforts and collaborative networks, we can cope with nuclear security challenges now and in the future.

[33] Udum, "INSEN As Part and Propellant of Nuclear Security Regime."

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COMMENTARY

Addressing the biological security educational gap

Lijun Shang,[*] *Malcolm Dando,*[**] *and Weiwen Zhang*[***]

Abstract

Addressing the gap in dual-use research within the framework of responsible research under the Biological and Toxin Weapons Convention (BTWC) and the Chemical Weapons Convention (CWC) presents a significant challenge for all stakeholders, particularly within life science communities. While biosecurity education has long been recognized as a key strategy to address this issue, its effective implementation remains crucial. In this contribution, the authors provide an overview of the recently edited volume *Essentials of Biological Security: A Global Perspective*, describing its potential as a pivotal tool in addressing this gap. The book begins by underscoring the importance of enhancing biological security, particularly in the post-pandemic era, and defines biological security as the prevention of natural, accidental, and deliberate disease in humans, animals, and plants. While stressing the interrelated and critical nature of these aspects, the book primarily focus on the prevention of deliberate disease within the life sciences. In this context, the authors underscore and address the crucial role of scientists and their institutions, as highlighted by the World Health Organisation (WHO)'s Global Guidance Framework for the Responsible Use of the Life Sciences. In addition to delineating the structure and content of the book, its timeliness, significance, overarching objectives, and scope, this commentary proposes that, in the longer term, an International Biological Security Education Network (IBSEN), akin to the successful model of the International Nuclear Security Education Network (INSEN) managed by the International Atomic Energy Agency (IAEA), would be essential in effectively improving biosecurity.

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Biosecurity Education, Dual Use, Biological and Toxin Weapons Convention (BTWC), International Biosecurity Education Network (IBSEN), International Nuclear Security Education Network (INSEN)

Introduction

In the aftermath of the COVID-19 pandemic, the oversight of dual-use research has attracted high-level international policy discussions. Benignly intended life science research raises concerns about dual-use potential when it might be applied for malign purposes in political, security, intelligence, or military fields.[1] Moreover, the problem of the deliberate use of biological agents is expected to escalate in the coming decades as advances in biotechnology place increasingly sophisticated capabilities for malign misuse into more hands. The World Health Organisation's (WHO) new Global Guidance Framework for the Responsible Use of the Life Sciences asserts that: "A chronic and fundamental challenge is a widespread lack of awareness that work in the area of life sciences"—which is predominantly undertaken to advance knowledge and tools to improve health, economies, and societies—"could be conducted or misused in ways that result in health and security risks to the public".[2] Also, incentives to identify and mitigate such risks are lacking. Therefore, addressing this gap presents a challenging question. At present, life scientists face difficulties in raising awareness and improving biosecurity education due to this widespread lack of awareness and knowledge in this area. Therefore, significant efforts will be required to support the life science community in dealing with this issue.

The States Parties to the Biological and Toxin Weapons Convention (BTWC), which have agreed "never in any circumstances to develop, produce, stockpile or otherwise acquire or retain" biological or toxin weapons, have taken serious steps to address this issue by, *inter alia*, organizing working group meetings leading up to 10th Review Conference in 2028. Similarly, the recent Chemical Weapons Convention (CWC) Science Advisory Board's Report for the CWC Review Conference has emphasized the importance of biotechnology and the role of scientists in this context.[3] The Organisation for the Prohibition of Chemical Weapons (OPCW), especially in its recent medium-term plan, stresses the need for

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[1] Lars Klüver, Tara Mahfoud, Nikolas Rose, eds., *Opinion on 'Responsible Dual Use'*, EU Human Brain Project, 2018, https://www.humanbrainproject.eu/en/follow-hbp/news/opinion-on-responsible-dual-use-from-the-human-brain-project/.

[2] *Global guidance framework for the responsible use of the life sciences: mitigating biorisks and governing dual-use research*, Geneva: World Health Organization, 2022, p. 28.

[3] Report of the Fifth special session of the Conference of the States Parties to review the operation of the Chemical Weapons Convention (Fifth Review Conference), OPCW, June 7, 2023, https://www.opcw.org/resources/documents/conference-states-parties/fifth-review-conference.

education and the provision of detailed guidelines.[4] Additionally, non-governmental organizations and other international organizations are undertaking various initiatives to address this issue.

The authors contend that what is required now is the development of content and methodology for biosecurity education for life scientists and the establishment of a network to connect people working on these issues around the world. Although the task will need long-term attention, it is achievable with sufficient effort and resources. For example, a new grant awarded by the Joseph Rowntree Charitable Trust to London Metropolitan University's Biological Security Research Centre aims to help build an International Biological Security Education Network (IBSEN).[5] This initiative could lay the basis for a network focused on developing curricula and methodologies and connecting project initiatives in different countries and regions. The network could eventually be managed under the BTWC, similar to how the International Nuclear Security Education Network (INSEN) is managed by the International Atomic Energy Agency (IAEA) and the OPCW's Advisory Board on Education and Outreach (ABEO) focusing on outreach and education under the CWC. With its current interest in biosecurity education following the production of the new Global Guidance Framework, the WHO is also fully engaged in biosecurity education.

While there is a considerable amount of literature available that could be useful in such a dedicated biosecurity educational process for life scientists, this material is dispersed across various sources and rarely consolidated into formats that could easily be utilized by practicing life scientists in educational programs. In 2022, the authors initiated a project aimed at producing a series of books to summarize such material and create new content that can be used worldwide in biological security educational courses at schools, and universities, and for continuing professional education in the coming decades. The broad themes selected for the books series include all issues related to biosafety and biosecurity. This comprehensive approach will not only provide thorough coverage of the subject but will also appeal to a wide range of readers.

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[4] Report of the Credentials Committee on the credentials of representatives to the Fifth Special Session of the Conference of the States Parties to review the operation of the Chemical Weapons Convention, OPCW, May 18, 2023 , https://www.opcw.org/resources/documents/conference-states-parties/fifth-review-conference.

[5] "Biological Security Research Centre at London Met awarded charity funds", July 28, 2023, https://www.londonmet.ac.uk/news/articles/biological-security-research-centre/. International Biological Security Education Network, https://ibsen.org.uk/2024/06/26/book-launch-essentials-of-biological-security-a-global-perspective/.

The book series began with an edited volume titled *Essentials of Biological Security*: *A Global Perspective,* offering an overview of the entire landscape related to biosecurity, with contributions from over twenty international experts.[6] This will be followed by a second book that reviews practical examples of biological security education carried out in pioneering projects in recent years. Subsequent books will address specific issues related to the elements of the Tianjin Guidelines, which have recently been developed to assist in creating codes of conduct for the life science community in relation to the BTWC.[7]

In this contribution, the authors aim to present an overview of the first volume, explain its timeliness and importance, its aims and scope, and future perspectives. The authors have the ambition and hope the book will serve as a solid starting stone to address the aforementioned gap and the first practical step for building up IBSEN.

Scope and objective of the book

For the purpose of the book, biological security is defined broadly to encompass the prevention of natural, accidental, and deliberately caused diseases in humans, animals, and plants. The authors adopt a comprehensive approach that integrates both natural sciences and social science perspectives, with a particular focus on the potential for deliberate disease in future biological security. Specifically, the authors explore the role that scientists can play in preventing the hostile misuse of their benignly intended work.

Perceptions of deliberate biological threats have evolved rapidly in recent years, beginning at the start of this century with increasing concerns that novel biotechnologies could be used by terrorists to create biological weapons. More recently concerns have focused on potential state-level threats as the international system has become more unstable. Particularly after the pandemic showed once again how devastating disease outbreaks can be to human populations, the prevention of natural, accidental, and deliberate biological threats has received increased attention. Addressing this expanded range of threats in a coherent manner requires integrated actions in terms of both biosecurity and biosafety. One of the major difficulties anticipated for the future in assuring biosecurity lies in the extremely rapid pace of advances in the

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[6] Lijun Shang, Weiwen ZhangMalcolm Dando, eds., *Essentials of Biological Security: A Global Perspective,* (Wiley, 2024).

[7] *Tianjin Biosecurity Guidelines for Codes of Conduct for Scientists*, Johns Hopkins Bloomberg Center of Public Health Center for Health Security, Tianjin University Center for Biosafety Research and Strategy SHPIP, Tianjin: Tianjin University, 2021.

life sciences and related fields. While the specific topics of concern may vary according to the backgrounds and interests of different groups of stakeholders, this overarching theme of a rapidly growing threat emerges consistently in the attempts to assess the risks of future developments over the coming decades. However, the clear recognition of scientists and their institutions as key players in ensuring future biological security, along with the identified gap in their relevant knowledge and culture, poses a significant challenge, as highlighted again in the WHO's Global Guidance Framework. Therefore, the authors' objective in producing the book was to provide a "one-stop-shop" where any interested scientist or stakeholder could swiftly grasp the main issues involved in addressing the dual-use problem and ensuring biological security more broadly. Additionally, they aim for it to be easily used by educators to add material on biological security into their teaching of life and associated science courses according to different educational levels.

The challenges associated with integrating biological security into the education and culture of life sciences and related scientists should not be underestimated, given the vast numbers of such scientists worldwide, the disparate nature of the fields in which they work, and the rapid pace of advances being made in many of these research areas. A further factor that needs to be taken into account is that there is a growing demand for scientists to take part in discussions with governments to provide advice about how dual-use dangers are to be regulated.

Overview of book structure and chapters

In order to fulfil the objective of providing a comprehensive yet user-friendly source of information on biological security post-pandemic, the subjects covered in the book have been divided into twenty chapters organized into five sections: Introduction and Overview (one chapter); The Threat (seven chapters); The International Response (four chapters); The Role of Scientists (six chapters); The Future (two chapters). References have been kept to a limited number but selected to offer a swift route into more detailed literature for those requiring additional information or interested in further exploration of the discussed issues. Nonetheless, some chapters contain a larger numbers of references, as the authors deemed the topics they covered to be less familiar to readers compared to the rest of the book. For instance, the main sections of the WHO Global Guidance Framework document contain one hundred and fifty-four references, with additional references in the report's annexes.

The first requirement in raising awareness and improving biosecurity education entails ensuring that life and associated scientists have a better understanding of why biosecurity must be enhanced. Therefore,

following the overview and introduction of Section 1, Section 2 provides an extensive account of the history and current status of the threat. This section begins with Chapter 2 by Jean-Pascal Zanders, delving into the evolution of our understanding of poisons and infections over the past two centuries as chemistry and biology emerged as sciences, and of how the international community has attempted to prevent the hostile use of these new sciences. Following this, Chapter 3 by Gemma Bowsher examines past attempts to use biological weapons by various actors with different motives, as well as how the potential use of such weapons is now being exploited in disinformation campaigns and infodemics. Brett Edwards then explores the influence of scientific knowledge and context on the potential use of biological weapons from antiquity to 1946 in Chapter 4, while Chapter 5 by Brian Balmer reviews the offensive biological weapons programs of states during the latter half of the 20th century, including details of effective biological and toxin weapons produced during this period. In Chapter 6, Kathryn Nixdorff investigates the developing concerns about dual-use arising from experiments conducted in the early 21st century, followed by Xinyu Song and Weiwen Zang's description of cutting-edge technologies of concern today, focusing particularly on synthetic biology and genome editing in Chapter 7. The section on the threat concludes with Chapter 8 by Ralf Trapp, which discusses the increased concern about dual-use applications resulting from the convergence of technologies, such as artificial intelligence and machine learning with biotechnology.

Section 3 of the book then examines how the international community has endeavored to deal with this threat. It begins with Chapter 9, where Tatyana Novossiolova provides an account of the origin and development of the concept of the web of prevention. This is followed by Jeremy Littlewood's review of the structure and functions of the 1925 Geneva Protocol and the BTWC in Chapter 10, and Michael Crowley's examination of other relevant international agreements such as the CWC in Chapter 11. The section concludes with Chapter 12 by Louison Mazeaud, James Revill, Jaroslav Krasny, and Vivienne Zhang, which reviews the role of relevant international organizations such as the WHO and the International Committee of the Red Cross. This section contextualizes how informed and educated life and associated scientists can contribute to preventing the malignant misuse of their benignly intended work.

Within that broader context of national and international regulations, Section 4 of the book shifts focus to the key role that life and associated scientists can play in improving biosecurity. It begins with Chapter 13 by Mayra Ameneiros, which reviews the elements of biorisk management, followed by Chapter 14 by Dana Perkins and Lela Bakanidze, which describes two national regulatory systems, one in the United States and the other in Georgia. Nariyoshi Shinomiya then investigates the lessons

derived from recent experiences with enhanced Potential Pandemic Pathogen (ePPP) research and the COVID-19 pandemic in Chapter 15. The subsequent chapters address the development and effective implementation of biosecurity codes of conduct. Yang Xue reviews the Hague Ethical Guidelines developed under the CWC and the Tianjin Biosecurity Guidelines for the BTWC in Chapter 16, followed by Yahan Bao and Alonso Flores's discussion of engaging scientists in biorisk management in Chapter 17. This section culminates in Chapter 18 by Leifan Wang, which examines the challenging issue of involving scientists in social science fields such as appropriate ethics and its application. The book concludes with Chapters 19 and 20 in Section 5, which focus on the future. Nancy Connell and Gigi Gronwall analyze the multi-layered system of different components involved in efforts to prevent the misuse of life and associated sciences effectively in Chapter 19. Finally, Kathryn Millett and Lijun Shang stress the urgent need to establish an International Biosecurity Education Network to support the effective biosecurity education of life and associate scientists in support of the Tianjin Biosecurity Guidelines in Chapter 20.

Final thoughts and future directions

In conclusion, it becomes evident that the comprehensive structure of the book, coupled with its user-friendly approach, aims to fill a crucial gap in the availability of resource materials for teaching biosecurity. By dividing the subjects into 20 chapters organized into five sections, the authors have endeavored to provide a thorough yet accessible resource for lecturers and teachers in universities and colleges. The author's hope is that this book will not only assist lecturers and teachers in incorporate biosecurity elements into their courses but also contribute significantly to raising awareness and enhancing education in this vital field. Additionally, the authors plan to translate the book into major languages, in line with their broader objective of fostering global engagement and collaboration, particularly in the development of IBSEN. Through these concerted efforts, the authors aim to facilitate a more informed and proactive approach to addressing the challenges of biological security in the post-pandemic era.