

Strengthening the Biological Weapons Convention

Briefing Paper No 7 (Third Series)

Effective and Sustainable Biosecurity Education for those in the Life Sciences: The Benefits of Active Learning

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EFFECTIVE AND SUSTAINABLE BIOSECURITY EDUCATION FOR THOSE IN THE LIFE SCIENCES: THE BENEFITS OF ACTIVE LEARNING

by Tatyana Novossiolova^{*}, Giulio Mancini[†] and Malcolm Dando

Introduction

1. For education to be effective, attention has to be given both to the **content** of what is being taught and the **method** being used for the particular group being educated. This paper is concerned with the **method** of education. To date, when the States Parties to the Biological and Toxin Weapons Convention (BTWC) have addressed education and awareness-raising attention has been given primarily chiefly to **content**. Thus, at the Seventh Review Conference of the BTWC, the States Parties agreed¹ in regard to Article IV of the Convention that:

13. The Conference notes the value of national implementation measures, as appropriate, in accordance with the constitutional process of each State Party, to:

- (a) implement voluntary management standards on biosafety and biosecurity;*
- (b) encourage the consideration of development of appropriate arrangements to **promote awareness** among relevant professionals in the private and public sectors and throughout relevant scientific and administrative activities and;*
- (c) promote amongst those working in the biological sciences **awareness of the obligations** of States Parties under the Convention, as well as relevant national legislation and guidelines; [Emphasis added]*

2. In addition, the States Parties at the Seventh Review Conference in regard to education and associated topics agreed Standing Agenda Items to be addressed at both the Meeting of Experts and Meeting of States Parties each year during the Intersessional Programme between 2012 and 2015. The Standing Agenda Item² on *Review of Developments in the Field of Science and Technology related to the Convention* includes the topic:

(e) education and awareness-raising about risks and benefits of life sciences and biotechnology.

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¹ United Nations, The Seventh Review Conference of the States Parties to the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction, Geneva, 5-22 December 2011, *Final Declaration in Final Document*, BWC/CONF.VII/7, 13 January 2012. Available at www.unog.ch.

² United Nations, The Seventh Review Conference of the States Parties to the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction, Geneva, 5-22 December 2011, *Final Declaration in Final Document*, BWC/CONF.VII/7, 13 January 2012. Available at www.unog.ch

In addition, the Standing Agenda Item³ on *Strengthening National Implementation* includes the topic:

(d) national, regional and international measures to improve laboratory biosafety and security of pathogens and toxins;

3. At the Meeting of States Parties to the BTWC held in December 2012, it was recognised in a Working Paper⁴ submitted by Canada that:

the incorporation of bioethics and dual-use issues within the curriculum on biosafety and biosecurity allows for a comprehensive approach to the education and awareness-raising of life scientists.

In addition, it was recommended⁵ that education programmes designed to inculcate awareness of the legal, social and ethical aspects of modern biotechnology should address *inter alia*:

- a) the concepts of biosafety, biosecurity and bioethics, as well as their relevance to life sciences;*
- b) relevant national and international oversight, including import/export controls and the Convention;*
- c) biosafety, biosecurity, dual-use and bioethical risks of life sciences;*
- d) approaches for the management of research and responsible conduct of research;*
- e) dual-use conundrums and dilemmas that arise due to the impact of science and technology on society; and*
- f) communication dilemmas that arise due to ethical, legal and social considerations.*

It is evident from this example that the discussion of biosecurity education for those engaged in the life sciences has predominantly focused on determining the **content** of education and awareness-raising programmes, that is, the topics, issues and dilemmas that they should address.

³ United Nations, The Seventh Review Conference of the States Parties to the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction, Geneva, 5-22 December 2011, *Final Declaration in Final Document*, BWC/CONF.VII/7, 13 January 2012. Available at www.unog.ch.

⁴ Canada, Meeting of State Parties to the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction, Geneva, 10-14 December 2012, Item 7 of the Provisional Agenda, Standing Agenda Item: Review of Developments in the Field of Science and Technology Related to the Convention, *Considerations and Recommendations to Inculcate Awareness of the Dual-Use Challenge into Biosafety and Biosecurity Training and Education for Life Scientists in State Parties*, BWC/MSP/2012/WP.4, 3 December 2012. Available at: <http://daccess-dds-ny.un.org/doc/UNDOC/GEN/G12/638/45/PDF/G1263845.pdf?OpenElement>.

⁵ Canada, Meeting of State Parties to the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction, Geneva, 10-14 December 2012, Item 7 of the Provisional Agenda, Standing Agenda Item: Review of Developments in the Field of Science and Technology Related to the Convention, *Considerations and Recommendations to Inculcate Awareness of the Dual-Use Challenge into Biosafety and Biosecurity Training and Education for Life Scientists in State Parties*, BWC/MSP/2012/WP.4, 3 December 2012. Available at: <http://daccess-dds-ny.un.org/doc/UNDOC/GEN/G12/638/45/PDF/G1263845.pdf?OpenElement>.

4. Considerable attention has been given to the need to raise awareness of the Convention and of the potential security concerns arising from the advances in the life sciences. In this regard, the contribution made by various stakeholders should be recognised. An example is the work carried out at the University of Bradford in the United Kingdom and the Landau Network-Centro Volta in Italy. The Bradford Disarmament Research Centre (BDRC), together with colleagues from the National Defence Medical College, Japan and the Landau Network-Centro Volta, have successfully developed a Biosecurity Education Module Resource (EMR) comprising of 21 lectures accompanied by lecture notes, self-study materials and essay questions. The Biosecurity EMR⁶ is freely available online currently in ten languages, including English, Japanese, Russian, French, Spanish, Urdu, Polish, Romanian/Moldovan and Georgian.

5. The Landau Network-Centro Volta (LNCV) in Italy has been involved in awareness-raising among young scientists, and has provided expert advice on contents development for biosecurity education through the creation of networks between organizations and life science faculties in various countries. In 2011, several life science faculties across Europe interested in the incorporation of biosecurity and dual use into their curricula were partners in a project coordinated by LNCV and co-funded by the European Commission Prevention of and Fight against Crime programme (ISEC) known as the European Biosecurity Awareness Raising Network (EUBARNet).⁷ Membership in the Network has enabled local faculties to invite speakers from other European countries; to collect multimedia materials and share them online with students; and to gather and access feedback from students and colleagues.

6. Although significant effort has been devoted to determining and clarifying the **contents** of biosecurity education programmes, so far little attention has been given to the **method** or the **means** by which such education should be delivered to those engaged in the life sciences. Interactive teaching methods, including seminars, role-plays and table-top exercises, if utilised, tend to complement rather than substitute for more traditional lecture-based approaches. Since the topics that biosecurity education aims to address pertain not only to the technical dimensions, but also to the legal, social and ethical implications of the life sciences, their relevance to biotechnology is not always immediately recognised. Hence, the development and implementation of **effective** biosecurity education programmes depends as much on the adoption of appropriate approaches and methods of delivery as on the contents of such programmes. Given the substantial body of evidence suggesting that *'humans are not adept at making connections between disparate fields or types of knowledge, unless they are specifically helped to do through education'*,⁸ it is of paramount importance that the **delivery** of biosecurity education is tailored to the needs of those engaged in the life sciences.

The Chemical Weapons Convention

7. The States Parties to the Chemical Weapons Convention have recognised the importance

⁶ The Biosecurity Educational Module Resource constitutes open-source lecture contents available at: <http://www.brad.ac.uk/bioethics/educationalmoduleresource/>.

⁷ The European Biosecurity Awareness Raising Network, www.eubarnet.eu.

⁸ Committee on Developments in the Science of Learning with additional material from the Committee on Learning Research and Educational Practice, National Research Council, *How People Learn: Brain, Mind, Experience, and School* (expanded version), The National Academies Press, Washington, 2000. See also Jane Johnson, 'Teaching Ethics to Science Students: Challenges and a Strategy' in Brian Rappert, ed. *Education and Ethics in the Life Sciences: Strengthening the Prohibition of Biological Weapons*, ANU Press, Canberra, 2010.

of education and outreach⁹. At the 17th meeting of the Scientific Advisory Board of the CWC in November 2011, the Director-General¹⁰ in a session considering the future priorities of the OPCW, *underlined the need to refocus the OPCW's activities through the deepening of some of its programmes and through the establishment of a new balance between activities to prevent the re-emergence and misuse of toxic chemicals on the one hand, and international cooperation and assistance on the other*. The Director-General went on to say:

*14.2 In the context of prevention, the Director-General referred, inter alia to the need, through **educational outreach, to raise awareness among the academic community and industry of the dual-use risks associated with toxic chemicals**. To this end, he expected that the SAB would provide important inputs. With regard to chemical safety and security, both training and using the Organisation as a platform for identifying and disseminating best practices would be important elements in this process. [Emphasis added]*

9. At that same SAB meeting¹¹:

16.5 The SAB noted the role that education and outreach could play in chemical safety and security.

16.6 The SAB recommended the establishment of a temporary working group on education and outreach, which would build upon earlier work done by the SAB. The SAB proposed that the group be chaired by Djafer Benachour.

10. At the 18th meeting¹² of the Scientific Advisory Board of the CWC on 16 – 19 April 2012, the SAB received a comprehensive report on the TWG on Education and Outreach, following the first meeting of the TWG, which was held on 12 and 13 April 2012. It was reported¹³ that *The main recommendations of the TWG were that educational and outreach materials should be prepared, not only in the form of books and printed documents, but also in the form of electronic platforms, documentaries, and short video films; in addition, the suggestion was made to take advantage of other education and outreach activities made by similar organisations, international scientific bodies, professional associations, and non-governmental organisations (NGOs).*

11. The terms of reference¹⁴ of the TWG on Education and Outreach include the requirement to report to the SAB on the following:

⁹ Thanks to Graham S. Pearson, Visiting Professor of International Security in the Division of Peace Studies at the University of Bradford for pointing out the recognition given by the Chemical Weapons Convention to education and the importance of e-learning.

¹⁰ Scientific Advisory Board, Organisation for the Prohibition of Chemical Weapons, *Report of the Seventeenth Session of the Scientific Advisory Board*, SAB-17/1, 23 November 2011. Available at <http://www.opcw.org>

¹¹ Scientific Advisory Board, Organisation for the Prohibition of Chemical Weapons, *Report of the Seventeenth Session of the Scientific Advisory Board*, SAB-17/1, 23 November 2011. Available at <http://www.opcw.org>

¹² Scientific Advisory Board, Organisation for the Prohibition of Chemical Weapons, *Report of the Eighteenth Session of the Scientific Advisory Board*, SAB-18/1, 19 April 2012. Available at <http://www.opcw.org>

¹³ Scientific Advisory Board, Organisation for the Prohibition of Chemical Weapons, *Report of the Eighteenth Session of the Scientific Advisory Board*, SAB-18/1, 19 April 2012. Available at <http://www.opcw.org>

¹⁴ Scientific Advisory Board, Organisation for the Prohibition of Chemical Weapons, *Report of the Eighteenth Session of the Scientific Advisory Board, Appendix 2 Terms of Reference of the Temporary Working Group on Education and Outreach in Science and Technology Relevant to the CWC*, SAB-18/1, 19 April 2012. Available at <http://www.opcw.org>

a. Ways in which to raise awareness of the Convention in the education sector, in particular through:

- i. the development of teaching materials;*
- ii. promoting faculty development and student exchange;*
- iii. promoting the inclusion of the Convention in educational curricula.*

and also

d. Existing initiatives in this area with a view to avoiding duplication and allowing the OPCW to build relationships with other international organisations, professional associations, networks etc;

12. At the next meeting¹⁵ of the SAB in September 2012, the Chair of the TWG on Education and Outreach gave a report which emphasized *new educational techniques, and recent outreach tools related to chemistry education and outreach activities*. The TWG on Education and Outreach held their next meeting a month later in November 2012, when its report¹⁶ noted that:

A guest presentation was given by Masamichi Minehata of the University of Bradford in the United Kingdom. The presentation demonstrated action plans, developed by the University of Bradford, to achieve strategic objectives set out in the Final Document of the BWC Meeting of States Parties in 2008. The action plans included the following:

- (a) Conducting country surveys of life science degree courses to investigate the current state of biosecurity education at universities in Europe, the Middle East and the Asia-Pacific region;*
- (b) Developing online educational material to mitigate the lack of textbooks;*
- (c) Developing a train-the-trainer programme to mitigate the lack of teachers;*
- (d) Developing country specific educational material for short courses to help facilitate the development of national biosecurity experts networks; and*
- (e) Reporting activities back to the BWC.*

Mr Minehata noted that education and awareness-raising efforts by BWC States Parties are well documented in working papers submitted to the Seventh BWC Review Conference. Mr Minehata said that these examples can help States Parties understand how educators can enhance their own understanding about biosecurity issues. They should also help States Parties understand how to then disseminate knowledge through developing their own customised and tailored education programmes within

¹⁵ Scientific Advisory Board, Organisation for the Prohibition of Chemical Weapons, *Report of the Nineteenth Session of the Scientific Advisory Board*, SAB-19/1, 12 September 2012. Available at <http://www.opcw.org>

¹⁶ Temporary Working Group on Education and Outreach in Science and Technology relevant to the Chemical Weapons Convention, Scientific Advisory Board, Organisation for the Prohibition of Chemical Weapons, *Report of the Second Meeting of the SAB Temporary Working Group on Education and Outreach in Science and technology relevant to the Chemical Weapons Convention*, SAB-20/WP.1, 25 February 2013. Available at <http://www.opcw.org>

their own life science communities, being cognizant of the principle that “no one size fits all”. Mr Minehata said that education for life scientists, policy-makers and other stakeholders about social responsibility on dual-use issues is easily achievable and need not be expensive, time-consuming or over-burdening.

13. In looking ahead to the Third Review Conference to be held in April 2013, the TWG on Education and Outreach observed¹⁷ that:

It was noted that the final reports from the First and Second Review Conferences did not contain specific references to education, although they did contain general statements about the value of awareness-raising. In contrast, past BWC Review Conferences and Meetings of States Parties have made specific mention of education, and BWC States Parties have submitted several national papers on the topic. For example, the Seventh BWC Review Conference noted that oversight, education, awareness-raising and codes of conduct have a role to play in preventing the misuse of biological agents. In addition, a group of 11 BWC States Parties submitted a working paper on possible approaches to education and awareness-raising among life scientists. TWG members recommended that States Parties should discuss approaches to education and outreach at the Third Review Conference and that appropriate language should be included in its final report. They also encouraged States Parties to share their own experiences, perhaps through the submission of national papers. Such experiences could also be shared at a side event organised during the Third Review Conference.

14. The conclusion of the November 2012 meeting included:

(d) The TWG recommends that education and outreach is seen as an essential element of national implementation and is of the view that it will play an important role in preventing the misuse of toxic chemicals;

(e) The TWG believes that there are important lessons for the OPCW from education and outreach activities under the BWC, for example the utility of “train the trainer” programmes, the value of States Parties reporting on their experiences of education and outreach and the opportunities provided for interaction with the scientific community by structured meetings. The OPCW should therefore strengthen its interaction with the BWC;

and also that:

(h) States Parties should discuss education and outreach in the context of the Third Review Conference, for example through national papers and side events, and the TWG encourages the inclusion of appropriate language on the importance of education and outreach in the final report of the Review Conference;

¹⁷ Temporary Working Group on Education and Outreach in Science and Technology relevant to the Chemical Weapons Convention, Scientific Advisory Board, Organisation for the Prohibition of Chemical Weapons, *Report of the Second Meeting of the SAB Temporary Working Group on Education and Outreach in Science and technology relevant to the Chemical Weapons Convention*, SAB-20/WP.1, 25 February 2013. Available at <http://www.opcw.org>

15. The preparation for the Third Review Conference 8 to 19 April 2013 saw much work being carried out by the Open-Ended Working Group of States Parties during the previous year in preparing a draft provisional text¹⁸. This was issued on 28 March 2013 for the States Parties to draw upon during the Third Review Conference. In a section entitled The general functioning of the Organization for the Prohibition of Chemical Weapons, this contains the following language, originally proposed by the United Kingdom:

113. The Third Review Conference, having reviewed the general functioning of the OPCW:

(c) Called upon States Parties and the Secretariat, as part of efforts to promote the ethical norms of the Convention, to encourage and promote efforts by the appropriate national and international professional bodies to inculcate awareness amongst scientists and engineers at an early stage in their training that the knowledge and technologies used for beneficial purposes can also be misused for harmful purposes;

16. In addition, the importance of e-learning was recognised in three places in the provisional text. The first was in a section entitled National Implementation measures the following language, originally proposed by the United States of America, is included:

69. The Third Review Conference, having reviewed national implementation measures:

(g) Encouraged the Secretariat to expand the use of contemporary technological developments to assist and promote its training methods, including further development of e-learning modules;

The second was in a section entitled Assistance and protection against chemical weapons, where the following language, originally proposed by the Chair of the Open-Ended Working Group, is included:

83. The Third Review Conference, having reviewed the assistance and protection against chemical weapons:

*(b) Encouraged the Secretariat to engage in more active cooperation with relevant regional and subregional organisations as well as international organisations that have mandates relevant to assistance and protection against chemical weapons. Such cooperation could include joint exercises and **training including by the use of e-learning modules**; [Emphasis added].*

And, the third in a section entitled Economic and technological development, where the following language, originally proposed by the United States of America, is included:

93. The Third Review Conference, having reviewed economic and technological development:

¹⁸ Organisation for the Prohibition of Chemical Weapons, Working Group for the Preparation of the Third Review Conference, *Draft Provisional Text*, WGRC-3/1, RC-3/CRP.1, 28 March 2013.

(o) Encouraged the Secretariat to expand the use of e-learning as one of the means for capacity-building and outreach activities.

17. At the Third Review Conference of the CWC, all of the above language was taken into the Final Document¹⁹ issued on 19 April 2013. In addition, some additional language, for paragraphs 9.101 and 9.103, was proposed jointly by Argentina and Australia. The Final Document of the Third Review Conference included the following language on education and e-learning:

National implementation measures

9.96 The Third Review Conference reaffirmed that full, effective, and non discriminatory implementation of Article VII is essential for the realisation of the object and purpose of the Convention.

*9.101 The Third Review Conference **acknowledged the role of education, outreach and awareness-raising as a relevant activity for the national implementation of the Convention, including awareness among academia and relevant scientific communities of the provisions of the Convention, the domestic laws and regulations relevant to the Convention.** Accordingly, the Third Review Conference welcomed the establishment of the SAB temporary working group on education and outreach. [Emphasis added]*

9.103 The Third Review Conference, having reviewed national implementation measures:

(a) Called upon all States Parties to adopt, in accordance with constitutional processes, the necessary measures to fully implement their obligations under the Convention ...

(d) Called upon all States Parties to keep the effectiveness of national implementation measures under review so as to ensure at all times that the provisions of the Convention are implemented within their territory or in any other place under their respective jurisdiction;

*(e) Encouraged the Secretariat, in concert with the SAB temporary working group on education and outreach, to assist States Parties, upon request, **in implementing education and outreach activities**, including by disseminating materials, conducting workshops and regional meetings;*

¹⁹ Organisation for the Prohibition of Chemical Weapons, Third Review Conference, *Report of the Third Special Session of the Conference of the States Parties to Review the Operation of the Chemical Weapons Convention*, RC-3/3, 19 April 2013. Available at <http://www.opcw.org>

(i) Encouraged the Secretariat to expand the use of contemporary technological developments to assist and promote its training methods, including further development of e-learning modules; [Emphasis added]

18. A subsequent section on Assistance and protection against chemical weapons includes the language:

9.118 The Third Review Conference, having reviewed the assistance and protection against chemical weapons:

*(b) Encouraged the Secretariat to engage in more active cooperation with relevant regional and subregional organisations as well as international organizations that have mandates relevant to assistance and protection against chemical weapons. Such cooperation could include joint exercises and training including by **the use of e-learning modules**; [Emphasis added]*

19. And the section on Economic and technological development includes the language:

9.131 The Third Review Conference, having reviewed economic and technological development:

(p) Encouraged the Secretariat to expand the use of e-learning as one of the means for capacity-building and outreach activities; [Emphasis added]

20. In addition, a subsequent section on the general functioning of the OPCW states:

The general functioning of the Organisation for the Prohibition of Chemical Weapons

9.155 The Third Review Conference, having reviewed the general functioning of the OPCW:

(d) Called upon States Parties and the Secretariat, as part of efforts to promote the ethical norms of the Convention, to encourage and promote efforts by the appropriate national and international professional bodies to inculcate awareness amongst scientists and engineers at an early stage in their training that the knowledge and technologies used for beneficial purposes should only be used for purposes not prohibited under this Convention; [Emphasis added]

21. It is thus evident that the States Parties to the Chemical Weapons Convention at their Third Review Conference in April 2013 clearly *acknowledged the role of education, outreach and awareness-raising as a relevant activity for the national implementation of the Convention, including awareness among academia and relevant scientific communities of the provisions of the Convention, the domestic laws and regulations relevant to the Convention.* It is also welcomed that they recognized the value of contemporary technological developments in training methods as they *encouraged the Secretariat to expand the use of contemporary technological developments to assist and promote its training methods, including further development of e-learning modules.* This recognition of *contemporary technological developments* in education is particularly relevant to this Briefing which focuses on the value of active learning and in particular on team based learning. The approaches outlined in this Briefing Paper in the context of promoting the national

implementation of the BTWC through education are equally relevant and applicable to the national implementation of the CWC.

22. The exchange of ideas between those engaged in the OPCW Technical Working Group (TWG) on education and outreach and those engaged in the BTWC meetings in Geneva will be facilitated by two individuals who participated in both the first and second meetings of the TWG, namely:

Jo Husbands, of the National Academy of Sciences, Washington, D.C., USA, and United States of America, and

Robert Mathews, of the Defence Science and Technology Organisation, Melbourne, Australia

and also by a participant in the second meeting of the TWG on education and outreach:

Stefan Mogl, of the Spiez Laboratory, Switzerland.

The Benefits of Active Learning

23. An effective strategy to encourage engagement among those engaged in the life sciences and in the chemical sciences with the issues of the safe use of the life sciences and of the chemical sciences and to empower them to take a pro-active approach in recognising, addressing and reducing the potential security concerns related to their work is to switch from **passive** to **active** learning. This Briefing Paper addresses the value and effectiveness of **active** learning in relation to those engaged in the life sciences by considering biosecurity and dual use education. These arguments are equally valid for those engaged in the chemical sciences.

24. This Briefing Paper reports on a recent interactive seminar, whereby a **Team-Based Learning** (TBL) approach was adopted to engage students with biosecurity and dual-use issues. This Briefing Paper concludes by setting out how **active** learning can be effectively and efficiently utilised globally for teaching biosecurity in higher education institutions – and will be equally applicable for teaching the corresponding issues for those engaged in the life sciences.

25. In 2010 the US National Academy of Sciences published a report²⁰ entitled *Challenges and Opportunities for Education about Dual Use Issues in the Life Sciences* which describes *the extent to which dual use issues are currently included in postsecondary education in the life sciences; the contexts in which education is occurring; and what needs exist that must be addressed to enable significant expansion of education of dual use issues*. In regard to the development and implementation of biosecurity education programmes, the report highlighted the importance of two themes. First, it reiterated²¹ the point that biosecurity

²⁰ Committee on Education on Dual Use Issues in the Life Sciences, National Research Council, *Challenges and Opportunities for Education about Dual Use Issues in the Life Sciences*, The National Academies Press, 2010. Available at http://www.nap.edu/catalog.php?record_id=12958

²¹ Committee on Education on Dual Use Issues in the Life Sciences, National Research Council, *Challenges and Opportunities for Education about Dual Use Issues in the Life Sciences*, The National Academies Press, 2010. Available at http://www.nap.edu/catalog.php?record_id=12958

concerns related to work with dual use potential and *social and ethical responsibility [...] can readily be integrated in laboratory learning, whether it is a formal undergraduate laboratory experience or graduate-level research*. The NAS report made the point that these could be approached within the framework of responsible conduct of activities in the life sciences, which embraces the wider array of issues that the community addresses to fulfil its responsibilities to society. Second, the report²² acknowledged that the *growing body of research about how individuals learn...and the most effective methods for teaching them* could offer valuable insights into how education about dual use issues could best be delivered. In particular, the report underscored that given the complexities of the social and ethical dimensions of dual use, teaching strategies that encourage reflection and critical thinking could tremendously enhance the effectiveness of biosecurity education and promote its sustainability. The report specifically drew attention to the value of **active** learning and how, when properly implemented, it enables students to acquire the skills necessary for the practical application of theories and concepts.

26. A critical component of **active** learning is that the learner, rather than the instructor, is at the centre and focus of the activities taking place in the classroom. As such, it is a learner-centred mode of instruction that stresses collaboration, enquiry and critical thinking. Active learning helps people take control of their own learning by enhancing people's abilities to recognise when they understand and when they need more information, thus allowing them to predict their performances on various tasks. Teaching practices congruent with active learning engage learners as active participants in their learning by focussing their attention on critical elements, fostering abstraction of common themes or procedures (principles), and evaluating their own progress toward understanding.²³ Sense-making, self-assessment and reflection on what worked and what needs improving are thus crucial elements of active learning approach.

27. The US National Academy of Sciences' report²⁴ *How People Learn: Brain, Mind, Experience, and School* which appeared in 2000 provided an extensive overview of the value and practical uses of teaching approaches that encourage **active** learning. The report showed that there is a substantial body of evidence that active learning approaches enhance learning generally, enabling students to transfer and extend what they have learnt in one context to new contexts. In addition, active learning strategies to instruction *have been shown to increase the degree to which students will transfer to new situations without the need for explicit prompting*. Overall, the report²⁵ strongly endorsed the benefits of active learning strategies underscoring that the:

²² Committee on Education on Dual Use Issues in the Life Sciences, National Research Council, *Challenges and Opportunities for Education about Dual Use Issues in the Life Sciences*, The National Academies Press, 2010.

²³ Committee on Developments in the Science of Learning with additional material from the Committee on Learning Research and Educational Practice, National Research Council, *How People Learn: Brain, Mind, Experience, and School* (expanded version), The National Academies Press, Washington, 2000. Available at <http://www.nap.edu/openbook.php?isbn=0309070368>

²⁴ Committee on Developments in the Science of Learning with additional material from the Committee on Learning Research and Educational Practice, National Research Council, *How People Learn: Brain, Mind, Experience, and School* (expanded version), The National Academies Press, Washington, 2000. Available at <http://www.nap.edu/openbook.php?isbn=0309070368>

²⁵ Committee on Developments in the Science of Learning with additional material from the Committee on Learning Research and Educational Practice, National Research Council, *How People Learn: Brain, Mind, Experience, and School* (expanded version), The National Academies Press, Washington, 2000. Available at <http://www.nap.edu/openbook.php?isbn=0309070368>

Integration of [active learning] instruction with discipline-based learning can enhance student achievement and develop in students the ability to learn independently. It should be consciously incorporated into curricula across disciplines and age levels.

28. Following this important conclusion, the University of Bradford held a seminar within the framework of the European Biosecurity Awareness Raising network (EUBARnet) series in which **active** learning strategies were used to raise awareness and engage students with biosecurity and dual use issues. The following sections provide a summary of the seminar and its results and findings, respectively.

Teaching Biosecurity through Active Learning

29. In November 2012 the University of Bradford, together with the Landau Network-Centro Volta and colleagues from the University of Turin, Italy and the University of Coimbra, Portugal held an interactive seminar on *Bioethics and Responsible Research*. The seminar was hosted on the premises of the School of the Life Sciences²⁶ at the University of Bradford and was conducted with the explicit endorsement of the School's Dean. The purpose of the seminar was to use an **active** learning strategy to raise awareness of the social, ethical and legal implications of modern biotechnology among students. The strategy adopted for the seminar was **Team-Based Learning**, a special form of **collaborative active learning** that uses a specific sequence of individual work, group work and immediate feedback to create a motivational framework, whereby the focus is shifted from conveying concepts by the instructor to the application of concepts by student teams. Team-Based Learning has been used since September 2012 in the Undergraduate Programmes in Pharmacy offered by the University of Bradford to enable students to better develop the skills, knowledge and capabilities necessary for a career in the field.

30. Thirty participants took part in the November 2012 seminar on *Bioethics and Responsible Research*. They were mainly undergraduate and postgraduate students from different courses, such as the life sciences, international relations, engineering and law, and a small number of tutors and biosecurity experts. From the outset, participants from different fields were divided into four teams so as to elicit as many as possible different perspectives in each team during the team exercises. In addition, the tutors and the two biosecurity experts present at the seminar were put into a separate additional team which enabled them to make informed contributions to the discussions in an informal, non-authoritative and non-intrusive manner. The results presented in the next section are based on all five teams participating in the seminar, that is, four teams comprising students and one team comprising tutors. The duration of the seminar was three hours. The seminar was held in the newly-opened University of Bradford's Team-Based Learning Laboratory fully equipped with multimedia audio-visual facilities that allowed using various computer-based applications and student response devices (known as 'clicker' devices). Each group was seated around a separate table with its own computer interface and clicker devices that allowed individual and group inputs to the IT control system. The exercise controller and the subject experts who led the discussions were able to follow everything from a central station. However, as discussed in the next section of

²⁶ Special thanks to Mrs Rebecca McCarter, Learning and Teaching Development Officer at the School of Life Sciences, University of Bradford for the guidance and logistical support she provided during the organisation and facilitation of the Seminar.

the paper, the absence of advanced classroom technology does not hinder the effective utilisation of Team-Based Learning, as the techniques can easily be adapted in to match different classroom settings. What is key here is the **active** learning process and the sequence of activities rather than the equipment.

31. The seminar consisted of five parts: a pre-reading exercise; an Individual Readiness Assurance Test (iRAT); a Team Readiness Assurance Test (tRAT); and two team-based application exercises. Participants were also required to fill in a two-part evaluation questionnaire: part 1 was completed at the start of the seminar and part 2 was completed after the final debrief. The overall structure of the seminar, as conducted on the day, is outlined in Table 1.

Table 1: Structure of the Team-Based Learning Seminar

| Seminar Phases | Description |
|---|---|
| 1. Pre-Reading Activity | <ul style="list-style-type: none"> • A set of materials designed to give participants a general overview of the issues to be discussed at the seminar • Disseminated about a week before the seminar |
| 2. Evaluation Questionnaire (part 1) | <ul style="list-style-type: none"> • Consists of questions about participants' expectations, previous experience with group-work exercises and familiarity with the topics to be discussed; • Distributed when participants have been assigned to teams |
| 3. Individual Readiness Assurance Test (iRAT) | <ul style="list-style-type: none"> • Consists of multiple-choice questions based on the pre-reading materials that aim to assess the extent of individual grasp of contents • Takes the form of a closed-book exam • Duration 15 minutes |
| 4. Team Readiness Assurance Test (tRAT) | <ul style="list-style-type: none"> • Completed in teams using the same test as the iRAT • Takes the form of a closed-book exam • Duration 15 minutes |
| 5. iRAT and tRAT Feedback Session | <ul style="list-style-type: none"> • The results of the iRAT and tRAT are compared • Challenging questions are clarified • Takes between 5-10 minutes |
| 6. First Team-Based Application | <ul style="list-style-type: none"> • Features a specific scenario related to the |

| | |
|---|---|
| Exercise | <p>seminar topic followed by a set of multiple choice options</p> <ul style="list-style-type: none"> • Working as a team, participants have to discuss the scenario, agree on an option and provide a rationale for their choice • Duration 20 minutes • Feedback and discussion |
| 7. Second Team-Based Application Exercise | <ul style="list-style-type: none"> • A practical exercise as part of which participants have to apply what they have learnt during the seminar to a particular task/problem • Duration 25 minutes • Feedback and discussion |
| 8. Evaluation Questionnaire (part 2) | <ul style="list-style-type: none"> • Consists of questions that seek to elicit participants' feedback on the quality, relevance and utility of the seminar • Preceded by a debrief session that allows participants to share their immediate views on the seminar |

32. A week before the seminar a set of pre-reading materials was distributed among participants. The set consisted of the following:

- Summary of the 2004 National Research Council's report '*Biotechnology Research in an Age of Terrorism*' – the Fink Committee report;
- Summary of the 2006 National Research Council's report '*Globalisation, Biosecurity, and the Future of the Life Sciences*' – the Lemon-Reiman report;
- Rebecca Carlson and Mark Frankel, '*Reshaping Responsible Conduct of Research Education*', AAAS Professional Ethics Report, vol.24:1, Winter 2011, pp.1-3. Available at <http://www.aaas.org/spp/sfrl/per/newper64.shtml>.
- Andreia Jorge *et al*, '*Environmental Aspects of Biosecurity and Practice Standards in Europe*', EUBARnet Review Series on Environmental Aspects, No.1, March 2012. Available at http://www.eubarnet.eu/?post_type=library&p=221.
- Maurizio Balisteri, '*Should We Improve Human Nature? The Philosophical Debate on Human Enhancement*', EUBARnet Review Series on Policy, Ethics and Security, No.6, June 2012. Available at http://www.eubarnet.eu/?post_type=library&p=535.

The chief objective of the pre-reading materials was to introduce participants to the issues of dual use and biosecurity by providing a general overview of the main concepts and issues. All participants were advised that they should familiarise themselves with the pre-reading materials before coming to the seminar. The first three readings were designated as essential and therefore, mandatory reading for the purposes of the seminar and the last two were included as examples of the wider context to help participants develop a more in-depth grasp of the matter.

33. At the start of the seminar, participants were asked to fill in a brief questionnaire regarding their expectations and hopes for the seminar, their motivation to take part in the

seminar, and their level of knowledge on the subject of dual use and biosecurity. The list of questions comprising the questionnaire is shown in Table 2. The results of the questionnaire are analysed in the next section.

Table 2: Questions included in the pre-seminar questionnaire

| Questions |
|---|
| 1. Please tell us what you hope to gain from today’s session |
| 2. Please give a summary of what the term ‘Dual-Use’ means to you |
| 3. Please give a brief description of your experience of working in teams or groups |

34. After completing the questionnaire, the participants were given a short individual quiz (iRAT) featuring five multiple-choice questions designed to assess their foundational knowledge and understanding from the pre-reading materials and prepare them for the subsequent problem-solving (application) exercises. Questions included: a definition of the “dual-use dilemma”; legal and ethical regulations on the dual use dilemma; recommendations of the Lemon-Relman report; recommendations of the Fink Committee Report; and responsible conduct of science. The quiz that was used during the seminar is presented in Table 3 with the correct answers indicated in bold font. Following the individual test, participants were asked **as a team** to answer the same questions. In this way, they could discuss which answer should be chosen and thereby clarify each others understanding of the issues involved. After the individual test and the team test had been completed, participants then had the opportunity to raise questions and make comments on what they had found easy/challenging and to ask for further clarification from the seminar facilitators. The results of both the iRAT and the tRAT are discussed in the next section.

Table 3: Individual Readiness Assurance Test (iRAT) and Team Readiness Assurance Test (tRAT) Sample Questions

| Questions | Multiple Choice Options |
|--|---|
| 1. Which of these statements best defines the dual-use dilemma? | <ul style="list-style-type: none"> a) Research that has both civilian and military application b) Research that has multiple applications c) Research that can be legitimately used for human betterment and, at the same time, misused for malevolent purposes d) Research that could be used more than once e) Research that could potentially have more than one end users |
| 2. Which of the following statements about the dual-use dilemma is true? | <ul style="list-style-type: none"> a) It does not raise any security concerns b) The scientific community is well aware of it c) It is covered by existing international and national policies d) The results of such research may |

| | |
|--|--|
| | <p>facilitate hostile misuse</p> <p>e) Such research is covered by comprehensive international and national regulations</p> |
| <p>3. Which of the following is not among the recommendations of the Fink Committee Report:</p> | <p>a) Dual-use research should not be published, or otherwise publicly disseminated</p> <p>b) The science community should be educated about the dual-use dilemma</p> <p>c) Experiments that would enable the weaponization of a biological agent should be subject to additional review before being performed</p> <p>d) Harmonised international system for oversight of the life sciences should be implemented</p> <p>e) Certain types of experiments should not be performed before they have undergone additional review</p> |
| <p>4. The Lemon-Relman Committee Report:</p> | <p>a) Highlighted the potential health and economic benefits of biotechnology rejecting any potential security issues</p> <p>b) Substantially expanded the threat spectrum to cover different branches of the life sciences, including pharmacology, synthetic biology, systems biology etc.</p> <p>c) Was designed to give an overview of the different applications of nanotechnology</p> <p>d) Focussed exclusively on developments in microbiology</p> <p>e) Avoided mentioning any security issues that may arise from the proliferation of novel technologies</p> |
| <p>5. In what way should the responsible conduct of research (RCR) education be reshaped to reflect the changing role of science in society?</p> | <p>a) No need for change, it is good enough as it is</p> <p>b) It should focus only on aspects related to the practice of life science research</p> <p>c) It should cover only examples of scientific misconduct, e.g. falsification, fabrication and plagiarism</p> <p>d) It should concentrate on issues arising in the conduct of science, rather than on its social influence</p> <p>e) It should require life scientists to consider the social, ethical and legal implications of their work</p> |

35. In the second half of the seminar, participants were given two problem-solving tasks that aimed to enhance their understanding of dual use and biosecurity through the practical application of the knowledge they had acquired thus far. The first exercise constituted a short scenario on a real-life dual use controversy, namely the debate on the creation of highly pathogenic Avian Influenza (H5N1) virus. The scenario read as follows:

In September 2011, a team of scientists from the University of Rotterdam in the Netherlands announced at a conference in Malta that they had successfully created a highly virulent mammalian-transmissible lethal strain of the H5N1 bird influenza virus. The story quickly got picked up by popular science media and by December the deadly sensation was in the spotlight worldwide. At about the same time, the National Science Advisory Board for Biosecurity (NSABB), a consulting body with an advisory capacity to the US Government, recommended that the research results detailing how the lethal virus was created should be published in a redacted form in order to prevent replication by individuals or governments with malevolent intent. Full information on the methods and materials used in the study, the Board maintained, should only be disclosed to those who need to know so that the benefits could be still be obtained and security guaranteed. In the debate that followed, it became clear that the Dutch scientists leading the H5N1 experiments were utterly unaware of the potential biosecurity, ethical and legal concerns arising from their work. Reaching consensus was further hampered by the fact that no mechanisms were in place for the dissemination of the research on a 'need-to-know' basis. In late March the US Government stepped into the debate by issuing a review policy which made provisions for the possible classification of high-risk scientific research. Around this time, the NSABB reversed its position, allowing the publication of the Dutch study in the journal Science.

Was there a better way to handle the H5N1 controversy? Which of the options below best summarises your view?

- A. The debate was unnecessary; the experiments should have been published in full straight after the Malta meeting*
- B. The debate was too lengthy but otherwise it was successfully resolved in favour of science; governments should not interfere with the work of scientists*
- C. Popular media is to be blamed for the prolonged debate: had they not exaggerated the story, the debate could have been avoided*
- D. The Dutch scientists should have not shared the research in Malta but should have published it quietly in Science without flagging any dual-use and biosecurity issues*
- E. The Dutch scientists should have considered the potential biosecurity concerns of their work and carefully addressed these in the manuscript before submitting it for publication*
- F. The Dutch scientists should have been aware of the dual-use potential of their work when the experiment was first conceived and they should have conducted a careful risk-benefit analysis of whether to conduct the work at all*
- G. The Dutch scientists should have not conducted the experiment in the first place*
- H. The paper should have been classified immediately after it was submitted for publication*

Participant teams were required to read through the scenario text and then to choose from the seven options provided what the best possible outcome of the controversy would have been. In doing so, they were required to discuss the scenario, debate each possible option and reach group consensus on the best possible outcome. They had to complete the task within 20 minutes. All teams were then required to announce their decision at the same time using a designated card and then give a rationale for their choice elucidating the reasoning behind their group decision. This was followed by a vigorous discussion on the different perspectives put forward.

36. The second application exercise sought to build upon the arguments and issues addressed in the preceding discussion encouraging participants’ creativity and imagination. As part of this task, the teams had to develop a poster design to raise awareness of dual use and biosecurity. Each team was then asked to elaborate on the ideas expressed on their posters and subsequently to vote for the poster they liked most. A competitive element was added to the exercise, as the best two poster designs were to be developed into full-scale posters and possibly presented at the BTWC Meeting of Experts in August 2013 in Geneva. The exercise was followed by a debriefing session on the overall quality and usefulness of the seminar.

37. In a similar way to the questionnaire at the start of the seminar, the participants were asked to answer questions regarding their seminar experience. The scope of the questions covered both the seminar itself and the topic of dual use and biosecurity. The list of questions comprising the questionnaire is presented in Table 4. It is worth highlighting that the two-part questionnaire used for evaluating participants’ experience was patterned on the surveys that Pharmacy students complete as part of their Team-Based Learning for the purpose of self-monitoring and critical assessment of results. The set of questions that made up the second part of the Evaluation Questionnaire is presented in Table 4.

Table 4: Questions included in the post-seminar questionnaire

| Questions |
|---|
| 4. What did you gain from the session today? |
| 5. Has your understanding of team and group work changed? If so, how? |
| 6. What are the important things to Remember about ‘Dual-Use’? |
| 7. Are there any other comments you’d like to feedback about today’s session? |

Seminar Results

38. **Pre-seminar Questionnaires.** Answers to the initial questionnaires reveal an interest in the prospective discussion on bioethics. Participants’ expectations of the seminars included learning about ethics, and/or about more specific issues of dual use, or potential security problems (mentioned by over 40% of participants). Over a quarter of the participants were convinced of the benefits of group-based activities citing their past experience and highlighting the benefits of collaborative work, discussion and exchange of opinions. The results of the questionnaire further indicated that most participants had achieved at least an initial grasp of the meaning of “dual use” after the pre-reading, as more than two-thirds of them underlined the potential of the life sciences of being used both for beneficial and harmful ends. Some of the participants already had some experience with the format of the seminar (in previous educational or professional contexts), while others were taking part in such an exercise for the first time. Participants identified positive features of team-based learning, among which the opportunity to develop better understanding of concepts through

knowledge-sharing and interaction with other team members from different disciplines. About a half of the participants stressed the value of group discussion to brainstorming, creative thinking and generating of novel ideas. Regarding the challenges of team-work, some participants indicated the difficulty in reaching consensus in decision-making. Answers from the pre-seminar questions are further detailed in Table 5 below.

Table 5: Answers to the pre-seminar questions

| Question | Type of Answer | Mentioned by % | Examples | |
|---|---|----------------|---|---|
| Please tell us what you hope to gain from today's session | To learn about ethics in the life sciences | 66% | "Understanding the ideas behind bioethics and its relevance" | "Identify some ethics aspects connected with biotechnology" |
| | To learn about dual use/security issues | 41% | Learn about "dual use, bioweapons and/or specific themes of controversy" | "Information about dual use agents" |
| | To experience teamwork and TBL | 28% | "An alternative innovative and engaging learning technique and format" | |
| | To have contacts with diverse opinions and experiences | 10% | "Insight from students from other faculties" | "Other beliefs and opinions" |
| Please give a summary of what the term 'Dual-Use' means to you | To have multiple applications | 24% | "Using a thing in two different ways" | "Two completely different applications" |
| | To have the potential for beneficial applications but also to be misused and/or cause risk or destruction | 69% | "That scientific research can potentially be used to improve the life society or to harm it" | "The application for hostile misuse of knowledge that is intended for the benefit of humans, animals and the environment" |
| | To have more than one user | 3% | "Anything that can have 2 or more users; in science, any type of research that can be looked at from 2 different angles." | |
| Please give a brief description of your experience of working in teams or groups | I had previous experiences during education | 34% | "Group work through university coursework" | "Very limited in university context" |
| | I had previous projects outside education | 10% | "Through my job which is based in team" | |
| | I consider it valuable to discuss different opinions, disciplines and cultural approaches | 10% | "I like the idea of interacting with other team members where you learn about your team member culture and personality" | "Very enjoyable to work with people across different disciplines just as you would in a real work place" |
| | Discussion can be challenging when different opinions are | 17% | "To get various insights into a subject topic or debate can sometimes slow down a | "Sometimes it just creates all different opinions and not reaching consensus" |

| | | | | |
|--|--|-----|---|--|
| | at stake | | process: too much debate and no actions” | |
| | Helps in developing ideas in a creative way and through discussion | 45% | “I got to better understand the questions from the answers from other team members, which I did not understand initially” | “It is a original and creative way to explore and analyse some problems” |

39. Individual Readiness Assurance Tests (iRAT) and Team Readiness Assurance Tests (tRAT). In the four questions of the individual quizzes (iRATs), participants performed well after the pre-reading, with an average 78% choosing the answer that was considered “correct”. Over 90% of participants thought that “[RCR] should require life scientists to consider the social, ethical and legal implications of their work”. Some of these questions were common to questionnaires used in previous seminars organized by the EUBARnet using traditional educational methods. Among these questions, the correct answers to the one on the understanding of “dual use”, was 91% in the seminars using team-based learning (TBL) and 56% in those using traditional educational formats (see Figure 1). Furthermore, the average share of correct answers increased between the iRAT and the tRAT (78% to 98%), something postulated by the team-based learning (TBL) theory, when students had to share their knowledge, discuss and reach consensus on an answer. More detailed results of iRAT and tRAT tests are presented in Table 6.

Table 6: Answers to iRAT and tRAT tests

| iRAT Tests (30 Active Participants; Percentage Rounded) | | |
|--|--|----------|
| Question | Correct Answer | % |
| Which of these statements best defines the dual-use dilemma? | Research that can be legitimately used for human betterment and, at the same time, misused for malevolent purposes | 87% |
| Which of the following statements about the dual-use dilemma is true? | The results of such research may facilitate hostile misuse | 69% |
| Which of the following is not among the recommendations of the Fink Committee Report | Dual-use research should not be published, or otherwise publicly disseminated | 67% |
| The Lemon-Relman Committee Report... | Substantially expanded the threat spectrum to cover different branches of the life sciences, including pharmacology, synthetic biology, systems biology etc. | 79% |
| In what way should the responsible conduct of research (RCR) education be reshaped to reflect the changing role of science in society? | It should require life scientists to consider the social, ethical and legal implications of their work | 93% |
| iRAT Average Score | | 78% |
| tRAT Tests (5 Teams; Percentage Rounded) | | |
| tRAT Average Score | | 98% |

Figure 1: The responses to “Which of these statements best defines the dual-use dilemma?” at six 2012 EUBARnet Seminars: 45 participants in active learning

seminars at University of Bradford and Delft Technical University²⁷ vs. 165 participants in lectures-based seminars at at University of Milan, University of Turin, University of Coimbra, University of Granada.

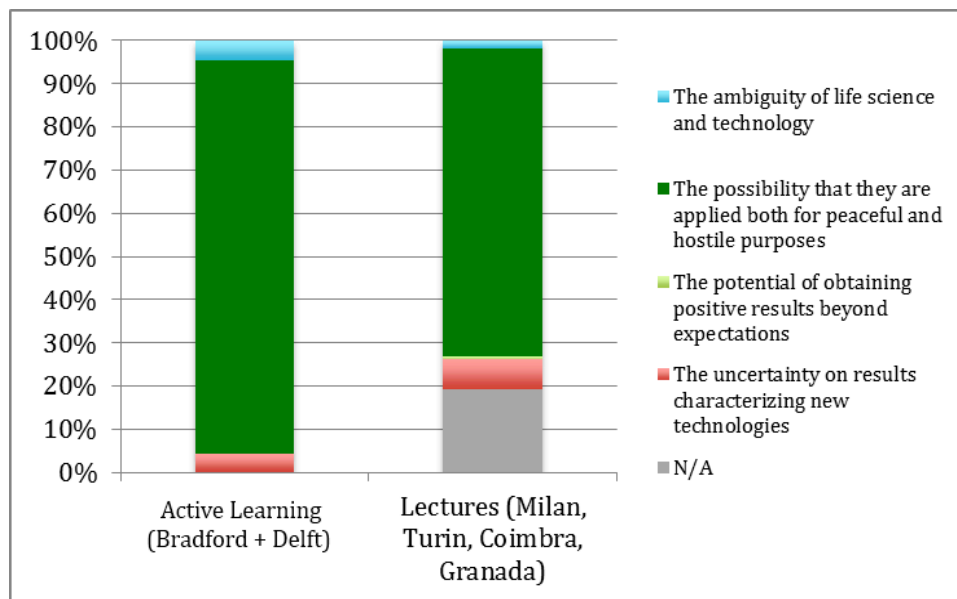
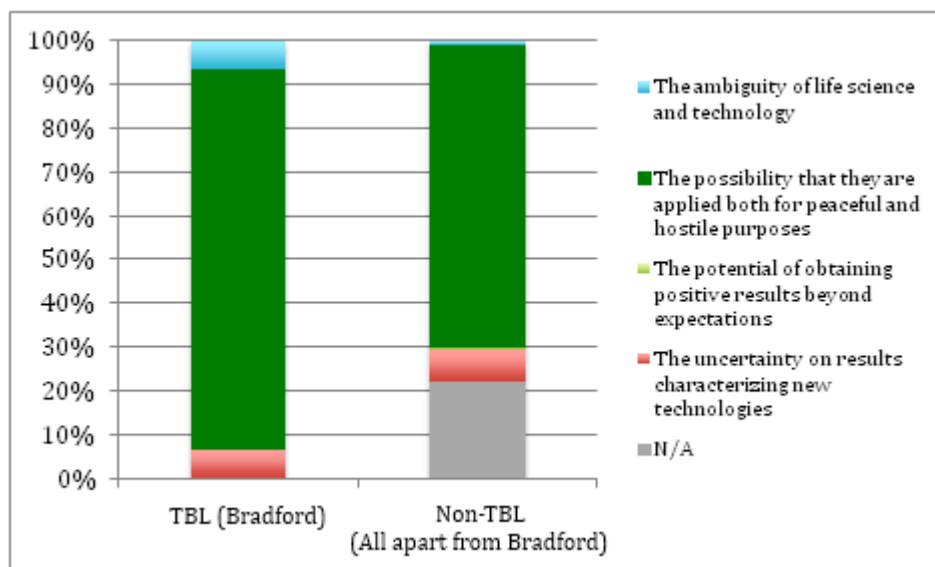


Figure 2: The responses to “Which of these statements best defines the dual-use dilemma?” 30 participants in Team Based Learning at University of Bradford vs 210 participants in non-Team Based Learning seminars at University of Milan, University of Turin, Delft Technical University, University of Coimbra, University of Granada.



²⁷ In June 2012 the University Delft held a Seminar on ‘Biosecurity: Designing a Web of Prevention’, which combined lectures with practical workshop, as part of which students were divided into small groups and asked to design a ‘web of prevention’ to prevent the hostile misuse of the life sciences. The seminar was conducted within the framework of the EUBARnet Project, coordinated by the Landau Network-Centro Volta. Further information about the seminar is available at http://www.eubar.net/?post_type=seminar&p=472.

40. First team-based application exercise. During the first application exercise the participating teams demonstrated an in-depth level of engagement with the issues raised in the scenario on the H5N1 Dutch experiment. From the start of the discussions, there was a general consensus that given the complexity of the conundrum, it was vital to search for a balanced approach, one that could minimise the potential security risks and challenges posed by the advancement of science while maximising the capacity of biotechnology for generating public goods. As a result, options A (*The debate was unnecessary; the experiments should have been published in full straight after the Malta meeting*), B (*The debate was too lengthy but otherwise it was successfully resolved in favour of science; governments should not interfere with the work of scientists*) and H (*The paper should have been classified immediately after it was submitted for publication*) were almost immediately rejected as counter-productive for attaining this goal. All teams generally agreed on the importance of academic freedom and the need for free exchange of data and materials among scientists in ways that do not pose a threat to the public. Consensus was also reached on the importance of fostering a constructive dialogue between the scientific community and policy-makers, for science did not exist in a vacuum but constituted an integral part of modern industrialised societies. In regard to option G (*The Dutch scientists should have not conducted the experiment in the first place*), while most participants were convinced of the value of the work conducted by the Dutch scientists, some maintained that broader consultations involving various stakeholders should have been held before the project was formally approved and funded. In the final choice of a best option, teams' position remained divided, as two teams favoured option E (*The Dutch scientists should have considered the potential biosecurity concerns of their work and carefully addressed these in the manuscript before submitting it for publication*) and three favoured option F (*The Dutch scientists should have been aware of the dual-use potential of their work when the experiment was first conceived and they should have conducted a careful risk-benefit analysis of whether to conduct the work at all*). Those in support of option E said that while the alternative choice (F) was highly desirable, it might be better if more stakeholders, other than the scientists in charge of the project were involved in the cost-benefit analysis, as this would increase transparency and prevent conflict of interest. All teams highlighted the importance of education and awareness-raising of biosecurity issues among life scientists, recognising at the same time that a wider engagement of interested parties, such as funding agencies, publishers, security experts and state authorities would be required for building a culture of responsibility in the life sciences.

41. Second team-based application exercise. Five poster designs were developed as part of the second application exercise. As the main objective of the task was to encourage creativity and practical application of knowledge and skills, no pre-prepared poster templates were used; rather it was left to the participating teams to choose the best way of organising their ideas of how to raise awareness of biosecurity and dual-use issues. Since all working stations in the room were equipped with computer screens, digital poster designs were produced using Microsoft Power Point. However, as discussed later in this section, all seminar activities can be easily and effectively replicated in the absence of advanced multimedia facilities with no detriment to participants' overall learning experience. It is worth noting that participating teams adopted different methodologies when designing their posters. Two of the teams chose to focus on conveying short clear messages using cartoon drawings, slogans and snappy phrases. One team presented an outline of a scenario that could be used in teaching bioethics to life science students. The two posters that received the highest ranking during the peer evaluation examined the 'dual' nature of modern biotechnology, presenting both the benefits that could be accrued from the life sciences and the potential for causing grave harm if such

knowledge and materials were misused for hostile purposes. *Advances in medicine, development of vaccines and enhancing public welfare by scientific progress* were thus juxtaposed with the *development of biological weapons, disease outbreaks and misapplication of benignly-intended research for causing system disruption (e.g. genomic medicine)*. To make their point more explicit, one of the teams used a balance design stressing the need for weighing the costs and benefits of modern biotechnology. Fostering a culture of responsibility in the life sciences and promoting awareness and education of the social, ethical and legal implication of biotechnology were presented as crucial elements of preventing the malevolent misuse of the life sciences.

42. Post-seminar Questionnaires. Answering the post seminar questionnaire, participants outlined their impressions on the experience. Around 20% of participants clearly stated that they had gained a better understanding of ethics, while over 30% were more specific mentioning ‘dual use’. Many chose to underline in their comments the insights gained on the basis of the Team-based Learning (TBL) format. The majority of participants defined the experience as enjoyable, underlining specific aspects, such as the opportunity to interact with people with diverse academic background, identify and correct deficiencies in their knowledge and grasp of the matter and openly exchange ideas and opinions. In the regard to the issue of dual use, one out of five participants underscored the value of extensive cost-benefit analysis and risk assessment prior to conducting life science experiments. About half of the class highlighted that raising awareness and education of biosecurity and bioethics could provide a safeguard against misuse, acknowledging that curtailing experimental work in the life sciences as a way of addressing dual-use conundrums would be counter-productive. Answers to the post-seminar questions are detailed in Table 7.

Table 7: Answers to the post-seminar questions

| Question | Type of Answer | Mentioned by % | Examples | |
|---|--|----------------|---|---|
| What did you gain from the session today? | Better understanding of research and science ethics | 21% | “Basic understanding/knowledge of possible procedures to reduce risks” | “A greater grasp of the perspective of life sciences students on ethics”; |
| | Better understanding of the dual use, misuse and security issues | 34% | “Got an understanding of this underlying idea of dual-use and what can be done to reduce the abuse of scientific research.” | “A better grasp of how the dual-use dilemma is and isn’t understood by scientists” |
| | Insights on TBL | 41% | “An alternative innovative and engaging learning technique and format” | “A nice interactive programme” |
| Has your understanding of team and group work changed? If so, how? | Interdisciplinarity helps bringing different views | 21% | “Working with people with different interests to you can help show different views of the same topic” | “The varied background of the group helped bring different opinions and perspectives in the disputes” |
| | Enjoyed teamwork, interaction and TBL | 34% | “I now see that bringing ideas together is always positive way of discussing” | “Mistakes can easily be identified” |
| | Helps to overcome | 7% | “Need to be open to other people’s opinions, and to allow them to persuade | “Need to be able to evaluate opinions” |

| | | | | |
|--|--|-----|---|--|
| | individuality and be open | | you.” | |
| | My understanding did not changed | 34% | | |
| What are the important things to remember about Dual-Use? | Awareness among scientists is important | 38% | “Awareness of the dual-use would provide the best safeguard in my opinion” | “Need of increasing the awareness of if and popularizing among the scientific society” |
| | Early risk consideration and assessment is important | 21% | “Needs consideration before research” | “Think, before doing any research study, to its future impact in society and nature” |
| | The issue is very complex | 10% | “The complexity of this issue, and its impact on everyday life in the future“ | “There’s a very blurry line between benefits and risks” |
| | There are potential risks and impacts on society to consider | 41% | “Carefulness: benefits as well as risks” | “Scientists should be really careful about the way their research can be used besides their main idea” |
| | Freedom of research/publication is important | 7% | “Should not stop searching in the face of the problems” | “Risk assessment and the importance of publicity on research” |
| | | | | |

43. Although the team-based learning seminar at the University of Bradford was conducted using advanced multimedia technology, featuring microphones, computers ‘clicker’ devices and software for data analysis, we are confident that all such Team-based Learning activities can be successfully carried out without such advanced multimedia facilities without disadvantage to the participants. For example, both the individual and the team Readiness Assurance Tests (iRATs and tRATs) can be carried out on paper without involving computers. While teams are carrying out the tRATs, facilitators have sufficient time to check and mark the iRATs so that the results of the two exercises can be compared. Similarly, the two application tasks do not require any sophisticated technology to be carried out effectively. As far as the scenario is concerned, hard copies of the scenario text and multiple choice options need to be distributed to all teams (one copy per team is sufficient), so that participants can read through the text, agree on an answer and provide a rationale for their decision. For the poster design, flipchart paper, markers, sticky notes and colour pens can be provided to each team. Participants are to decide how best to utilise the resources for preparing their poster design. It needs to be born in mind that the value of team-based learning lies not in the type of technology used but in the sequence of activities that allows students to acquire both theoretical and practical knowledge, develop skills and capabilities crucial for their future career and monitor their own progress by dint of reflection and self-assessment.

Conclusions

44. As the analysis of the seminar results presented in the previous section vividly demonstrates, **Team-Based Learning** is an efficient and effective technique for teaching biosecurity to university students, both at undergraduate and post-graduate level. The pre-reading exercise allows students to develop at least a basic grasp of the issues to be discussed

in class which in turn enhances their capacity for active engagement with the knowledge application tasks. Given the interactive nature of the format, students can take full ownership of the learning process, evaluate their performance and monitor their progress. Thanks to the application exercises, they are encouraged to apply the theories and concepts learned during the pre-reading and the individual and team Readiness Assurance Tests (iRATS and tRATs) in practice and thus acquire transferable skills necessary for their professional practice. The results of the iRATs and tRATs and the two application exercises presented in the previous section clearly support those conclusions. Moreover, the positive feedback provided in the two-part evaluation questionnaire further reinforces the value of team-based learning as an innovative, interactive and effective way of enhancing students' understanding of complex concepts that encourages critical thinking, reflection and collaborative work by giving students the unique opportunity to articulate and examine their own reasoning and explore a variety of different perspectives in search for an optimal solution.

45. Last but not least, as an active learning technique, Team-Based Learning can be utilised for teaching various subject matters, one of which is responsible conduct of activities in the life sciences.²⁸ Over the past few years there has been a growing recognition that while existing curricula on responsible conduct of activities in the life sciences cover in considerable detail the '*internal workings of science, and the responsibility to uphold community standards for doing science*', such courses have remained '*virtually silent on the social responsibilities of scientists*.'²⁹ As a result, it has been suggested that:

*[t]he evolution of professional practices, and our broadening understanding of the social and ethical responsibilities of scientists, requires us to assess [education of responsible conduct of activities in the life sciences] in order to call attention to the ways in which the curriculum can be reshaped to better prepare scientists for the future.*³⁰

Given the effectiveness of teaching biosecurity and dual-use bioethics using team-based learning, there are sufficient grounds to suppose that the format can also be effective in teaching the broader revised concept of responsible conduct of activities in the life sciences. Combining adequate education contents with a proven delivery technique that can be applied in various teaching settings and contexts could have a tremendous impact on engaging prospective life scientists at an early age with the ethical, social and legal implications of their work. It also could be seen as an important step toward fostering a culture of responsibility in the life sciences which would ensure that any attempt for misuse of related knowledge and materials is effectively discouraged and help to guarantee that biotechnology is utilised only for peaceful, prophylactic and protective purposes.

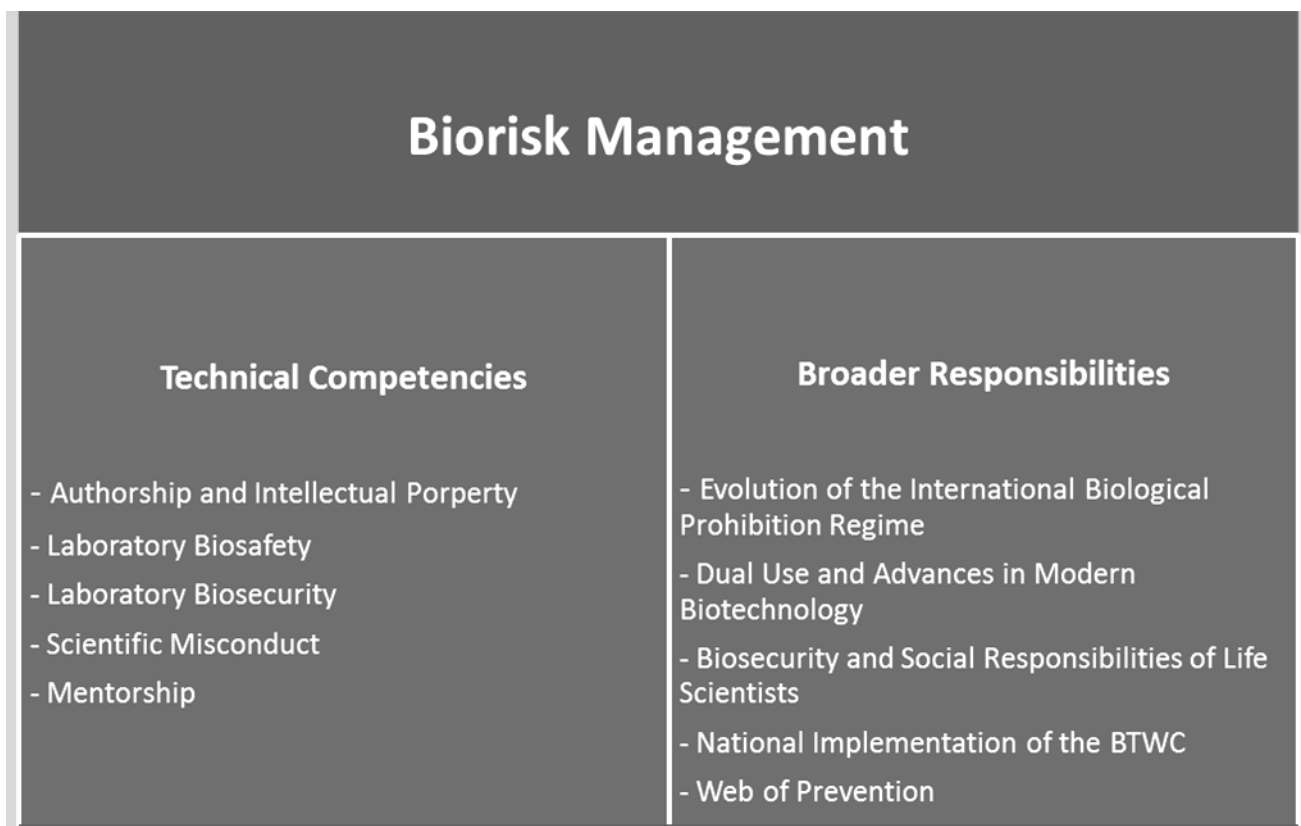
²⁸ Here the words 'responsible conduct of activities in the life sciences' are used to include the 'responsible conduct of research', as defined in National Academies of Science, *On Being a Scientist: A Guide to Responsible Conduct in Research*, (3rd ed.), The National Academies Press, Washington, 2009. Available at http://books.nap.edu/openbook.php?record_id=12192&page=R1.

²⁹ Rebecca Carlson and Mark Frankel, 'Reshaping Responsible Conduct of Research Education', *AAAS Professional Ethics Report*, vol.24:1, Winter 2011, pp.1-3. Available at <http://www.aaas.org/spp/sfrr/per/newper64.shtml>.

³⁰ Rebecca Carlson and Mark Frankel, 'Reshaping Responsible Conduct of Research Education', *AAAS Professional Ethics Report*, vol.24:1, Winter 2011, pp.1-3. Available at <http://www.aaas.org/spp/sfrr/per/newper64.shtml>.

46. It has not escaped our attention that the development of a small suite of Team-Based Learning exercises could be used in many different places and thus allow the use of the most efficient and effective method to be applied to correcting the present deficiency in the education of life scientists. To this end, a two-tiered integrated course in Bio-Risk Management covering both the technical competencies and skills related to life science practice and the broader social, ethical and legal responsibilities of life scientists could be developed using the Team-Based Learning format. A model of the course is presented in Figure 3. Tier 1 of such a course would address concepts related to the internal workings of science, such as authorship and intellectual property; scientific misconduct and negligence; laboratory biosafety; laboratory biosecurity; and mentorship. The second tier, by contrast, would address the broader scope of responsibilities incumbent upon those engaged in the life sciences. Five key concepts are indicative in this regard, including the evolution of the international biological weapons prohibition regime; dual use and recent advances in modern biotechnology; biosecurity and social responsibilities of life scientists; national implementation of the BTWC; and web of prevention. Based on these five concepts, an education package delivered by means of Team-Based Learning methodology could be designed and introduced to all undergraduate students in the life sciences worldwide. Given the proven effectiveness of Team-Based Learning, such a two-tiered course would be instrumental for raising awareness both of issues related to safe laboratory practices and to dual use and biosecurity among prospective life science students. Thus, the introduction of Team-Based Learning Bio-Risk Management course could be regarded as a fundamental step toward fostering a culture of responsibility amongst all those engaged in the life sciences.

Figure 3: A Model of a Team-Based Learning course for Life Scientists



Further Applications for Active Learning

47. At the BTWC Meeting of States Parties in December 2012, it was noted that the synthesis paper³¹ prepared by the Chairman and attached as the Annex I to the Report of the Meeting of States Parties³² recorded that:

2. States Parties recognized the importance of coordination with relevant international and regional organizations and other relevant stakeholders, specifically:

(a) Closer cooperation between the BWC and WHO, OIE, FAO and OPCW, in full conformity with their respective mandates;

(b) Greater interaction between the BWC and CWC scientific communities;

48. It was consequently encouraging to note that the importance of awareness raising and education were stressed by the States Parties to the Chemical Weapons Convention (CWC) in the Final Report³³ of the Third Review Conference held in April 2013 in which they agreed their:

***Determination** to maintain the Convention's role as a bulwark against chemical weapons; to that end to promote, inter alia, outreach, capacity building, education and public diplomacy. [emphasis in original]*

The Conference thus

*Called upon State Parties and the Secretariat, as part of efforts to promote the ethical norms of the Convention, to encourage and promote efforts by the appropriate national and international professional bodies to inculcate awareness among scientists and engineers **at an early stage in their training** that the knowledge and technologies used for beneficial purposes should only be used for purposes not prohibited under this Convention. [emphasis added]*

49. The commitment of States Parties to the CWC and the Organisation for the Prohibition of Chemical Weapons (OPCW) to the goal of education and awareness-raising among those engaged in chemistry is to be welcomed. It is evident that Active Learning would be a particularly effective approach to raising awareness of the Convention among those engaged in chemistry and this would substantially enhance the quality of education and outreach programmes and help ensure effectiveness and sustainability.

³¹ United Nations, Meeting of the State Parties to the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction, 10-14 December 2012, Geneva, *Synthesis of considerations, lessons, perspectives, recommendations, conclusions and proposals drawn from the presentations, statements, working papers and interventions on the topic under discussion at the Meeting of Experts*, BWC/MSP/2012/L.1, 1 October 2012. Available at <http://unog.ch/bwc>

³² United Nations, Meeting of the State Parties to the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction, 10-14 December 2012, Geneva, *Report of the Meeting of States Parties*, BWC/MSP/2012/5, 19 December 2012, Geneva, Switzerland, Available at <http://www.unog.ch/bwc>

³³ Organisation for the Prohibition of Chemical Weapons, Third Special Session of the Conference of the State Parties to Review the Operation of the Chemical Weapons Convention 8-19 April 2013, The Hague, *Final Report*, RC-3/3, 19 April 2013, The Hague, The Netherlands. Available at <http://www.opcw.org/rc3/documents-from-the-third-review-conference/>.

50. The OPCW and its Scientific Advisory Board (SAB) could play an important role in enhancing the level of awareness of the CWC among those engaged in chemistry. To this end, an effective and efficient approach would be the development of a short **active learning** course patterned on the one proposed for life scientists in the previous section. Such a course could be structured around the following five concepts:

- Evolution of the International Chemical Prohibition Regime
- Advances in Modern Chemistry and Convergence
- Chemical Security and Social Responsibilities of Chemists
- National Implementation of the CWC
- Web of Prevention

Such a course could with advantage be taught using the **Team-Based Learning** format. To facilitate its dissemination, the course could be delivered via an e-learning platform similar to the one currently in use by the University of Bradford for the Train-the-Trainer Master Course in Applied Dual-Use Biosecurity.³⁴ An online **Team-Based Learning** short course in chemical security could be instrumental in raising awareness of the CWC among those engaged in chemistry around the world and fostering a culture of responsibility in chemistry.

³⁴ More information on the Master-level online distance-learning Train-the-Trainer programme in Applied Dual-Use Biosecurity developed by the University of Bradford is available at <http://www.brad.ac.uk/bioethics/trainthetrainer/30creditbiosecuritymodule/>.