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**Fostering The Biosecurity
Norm: Biosecurity Education
for the Next Generation of
Life Scientists.**

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(LNCV), Como, Italy**

**Bradford Disarmament Research
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FOSTERING THE BIOSECURITY NORM: Biosecurity Education for the Next Generation of Life Scientists

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About the Landau Network-Centro Volta (LNCV)

The Landau Network-Centro Volta (LNCV) is a non-profit and non-governmental organization operating as a global network of international experts supporting global security, disarmament and cooperation. Its programs cover research on international security and policy issues, worldwide disarmament of Weapons of Mass Destruction, arms control, scientific and technologic cooperation for global peace support, water and energy security. LNCV is also the seat of the Executive Secretariat of the International Working Group (IWG), and informal think-tank of experts and officials participating in their personal capabilities.

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The Bradford Disarmament Research Centre is an internationally recognised centre of academic and policy-oriented research on the proliferation and control of nuclear, biological, chemical and conventional weapons and the national, regional and global security contexts in which these issues are salient.

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Abbreviations

AAAS	American Association for the Advancement of Science
ARWU	Academic Ranking of World Universities
BTWC	Biological and Toxin Weapons Convention
BW	Biological Weapons
CDC	Centers for Disease Control and Prevention [US]
CRDF	Civilian Research and Development Foundation [US]
CWC	Chemical Weapons Convention
DNA	Deoxyribonucleic acid
EC	European Commission
EU	European Union
FOI	Swedish Defence Research Agency
GLP	Good Laboratory Practice
GMO	Genetically Modified Organisms
KNAW	Royal Netherlands Academy of Arts and Sciences
MFA	Ministry of Foreign Affairs [Italy]
NAS	National Academy of Sciences [US]
NMDC	National Medical Defence College [Japan]
RNA	Ribonucleic acid
SMI	Swedish Institute for Infectious Disease Control
THES	Times Higher Education Supplement
UNSCR	United Nations Security Council Resolution
WHO	World Health Organization
WUR	World University Ranking

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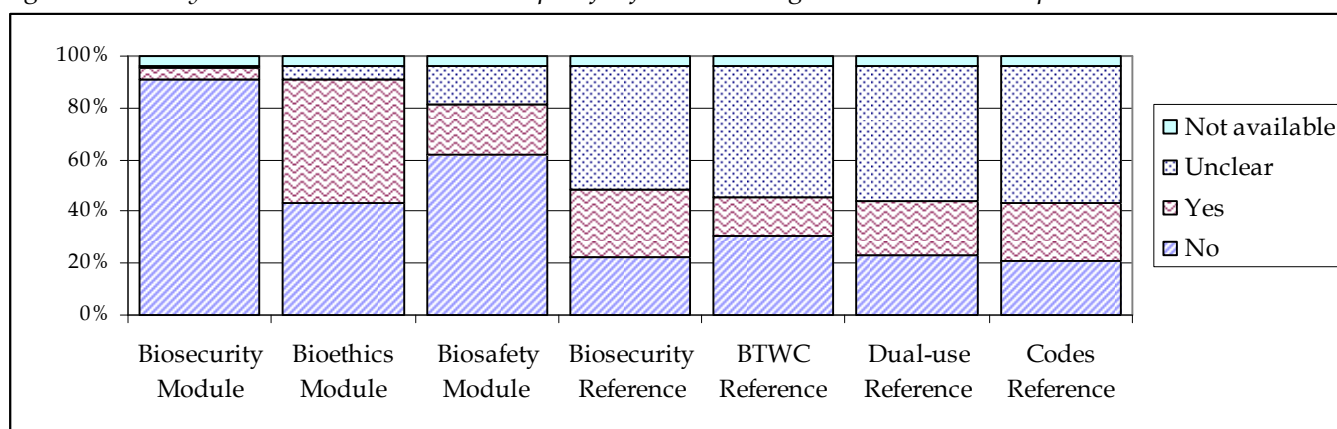
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Executive Summary

There have been various calls for some form of security orientated education and/or training for life scientists in fora such as the Biological and Toxin Weapons Convention, and there is growing interest in nurturing a culture of responsibility amongst life scientists. This report on biosecurity education was prepared to assist consideration of these issues at the December meeting of States Parties to the BTWC. The report begins by explaining the importance of biosecurity education, particularly for undergraduate life science students. It then proceeds to present the methodology and sampling techniques used in a survey on the extent of biosecurity education in life science degree courses in Europe and the attitudes of life science educators to biosecurity. Using a sample of 142 courses from 57 Universities in 29 countries speaking 25 different languages, we looked for evidence of biosecurity modules, bioethics modules and biosafety modules but also references to biosecurity, the BTWC, BW and/or arms control, dual use and codes of conduct (see figure 1).

This research suggested that only 3 out of 57 universities identified currently offered some form of specific biosecurity module and in all cases this was optional for students. There is evidence of a considerable number of bioethics modules and nearly half of the degree programmes surveyed evidenced some form of bioethical focussed module. In terms of biosafety modules, the investigation suggests that 27 of the 142 degree courses in Europe, roughly one fifth of life science degrees in the sample, contain a specific dedicated biosafety module although several of these specific modules were optional. Exactly what constitutes a reference varies; however, based on the quantitative data from the investigation, we found a total of 37 life science degree courses out of our sample of 142 where there was clear evidence of a reference to biosecurity. Only a minority of the degree courses in the study – a total of 22 out of 142 - made a reference to the BTWC, BW and/or arms control and a similar number, 29 degree courses, exhibited some reference to the dual-use issue whereas 31 life science degrees exhibited some form of reference to a code of conduct.

Fig1. Biosecurity Related Education in a Sample of Life Science Degree Courses in Europe



These results were presented at a Workshop and Round Table held in Como, on October 27th, 2008 in which biosecurity education was discussed with international biosecurity experts and life science lecturers. Many participants agreed that undergraduate level would be the best option in order to reach the widest number of students most effectively and that the educational content should include material on the Biological and Toxin Weapons Convention and national measures; the history of biological warfare and the role of scientists in past programmes; and the dual-use dilemma. It was further suggested that there is great merit to including "traditional" approaches to education, such as lectures, but other approaches may be a useful complement. Significantly, many felt that teaching on these issues should be a mandatory part of the curriculum in order to be most effective, however, it was recognised there may be difficulties in fitting biosecurity content into already busy teaching schedules. It was further recognised by participants that there is a lack of availability and suitability of biosecurity teaching materials for biosecurity education. To this end, the conclusions from the research process suggest that educational material is urgently needed and, on this basis, the next steps of the Landau-Bradford project will focus on the production of draft materials, and on testing their implementation.

1. Introduction

As the life sciences continue to advance in a changing geostrategic context, increasing attention from a broad range of actors has been allotted to the concept of biosecurity, one aspect of which is educating life scientists on the potentially malicious ramifications of their research. In the longer term, as biotechnology continues to advance education will become increasingly important as it engenders the possibility of creating a sustainable culture of responsibility which can help reduce the risk of the life sciences being misused for malicious purposes.

This report is based on the results of a joint research project between the Landau Network-Centro Volta (LNCV) and the Bradford Disarmament Research Centre (BDRC). In the next section, the paper frames the issue of biosecurity related education looking at the proposals for greater education and outlining why university life science students represent a useful target group for building a culture of awareness. The third section outlines the aims, methodology and sampling techniques used in an investigation of the biosecurity content of European life science education. In the fourth section, the quantitative and qualitative results of this investigation are presented, thus providing an illustrative insight into the extent of biosecurity related education but also an appreciation of the attitudes to such education. In the fifth section the themes and trends that emerged from a Workshop held in Como, Italy on the 27th of October, 2008 are discussed. This section provides an understanding of the questions that need to be considered in relation to the development, adoption and promulgation of biosecurity related education and the perspectives of participants on the way forward. The sixth section outlines the next steps of the Landau-Bradford project, including the collection and drafting of educational materials and lectures, but also tests in participating universities.

2. Framing the issue

The life sciences have contributed significantly to improving the human condition, and as the biotechnology revolution continues to unravel the fundamental life processes, it will increasingly provide human kind with the capability to control the building blocks of life. In this context, just as the information and communication technology revolution profoundly influenced the twentieth century, it appears that the advance of biotechnology and the life sciences will have an equally significant impact on the twenty-first century.

Yet this positive potential is ominously equalled by the potential for the misuse of the life sciences and by their capacity to cause unprecedented levels of destruction to human, animal and plant systems on a global scale. Various means and mechanisms have been employed at various levels - from the international to the individual - to prevent the misuse of science and these collectively form what has been termed a "web of prevention".¹ However, one theme which has received significant attention in the twenty first century is that of biosecurity.

Biosecurity is an essentially contested concept and competing definitions have been advanced.² Whilst recognising these conceptualisations, for the purpose of this investigation, biosecurity is understood as a collection of strategies and mechanisms intended to prevent the deliberate or inadvertent misuse of the

¹ See for example the work of the International Committee of the Red Cross ICRC (2004) "Biotechnology, Weapons and Humanity: introduction" available from: <http://www.icrc.org/web/eng/siteeng0.nsf/htmlall/5vdj7s?opendocument>; Rappert. B & McLeish. C (2007) "A Web of Prevention: Biological Weapons, Life Sciences and the Governance of Research", Earthscan Publications Ltd; and several articles by Graham Pearson, including Pearson. G. S (1998) "The Vital Importance of the Web of Deterrence", Proceedings of the Sixth International Symposium on Protection Against Chemical and Biological Warfare Agents, Stockholm, 11 - 15 May 1998, available at: <http://www.brad.ac.uk/acad/sbtwc/other/webdet.htm>

² In the 2003 BTWC meetings, Australia remarked that biosecurity "within Australian agriculture... also means protecting the country from exotic pests and diseases through quarantine, surveillance and early detection measures" adding "the FAO use it in terms of securing food supplies"; Australia (2003) "Intervention by Australia" BWC/MSP/2003/4 (Vol. II) Annex II, Page 125. There is also an underlying political-developmental issue, outside of the BTWC context, Indonesia has adopted a "broader approach" to biosecurity, suggesting it "encompasses biosafety import controls, and outbreak response training... Biosecurity is not limited to protecting laboratory-based pathogens and toxins from theft.... such a narrow strategy has limited value in Indonesia, where dangerous pathogens are not only located in laboratories, but can also be found readily in nature." See also Fidler. D & Gostin. L (2007) "Biosecurity in the Global Age Biological Weapons, Public Health, and the Rule of Law", Stanford University Press.

biological sciences for malicious purposes, specifically bioterrorism or biological warfare. In this regard, enhancing biosecurity requires a concerted multifaceted effort from a broad range of actors in different communities, one significant aspect of which is educating the life science community on their role and responsibility in preventing the malicious use of the life sciences.

Education is not a silver bullet for dealing with the range of potential problems posed by dual use expertise, materials and technologies; however, it remains an important element of any biosecurity strategy, something evident in the increased attention being given to some form of biosecurity related education in several forums, including, *inter alia*, the States Parties to the Biological and Toxin Weapons Convention (BTWC). Indeed, the Second, Third and Fourth BTWC Review Conferences have urged “*the inclusion in medical, scientific and military educational materials and programmes of information on the Convention and the 1925 Geneva Protocol.*”³ More recently, at the 2005 BTWC meetings on Codes of Conduct, many State Parties underlined the need to raise the awareness of life scientists over the dual-use concerns of the security community.⁴ There was sufficient support on this issue at the BTWC Sixth Review Conference in 2006 for a consensus statement to be added in the Article IV Additional Understanding, in which States Parties agreed:

*“...to promote the development of training and education programmes for those granted access to biological agents and toxins relevant to the Convention and for those with the knowledge or capacity to modify such agents and toxins, in order to raise awareness of the risks, as well as of the obligations of States Parties under the Convention.”*⁵

At the Sixth Review Conference, it was further agreed that, as part of the mandate for the Second Intersessional Process, States Parties would meet in 2008 to discuss, and promote common understanding and effective action on:

*“Oversight, education, awareness raising, and adoption and/or development of codes of conduct with the aim of preventing misuse in the context of advances in bio-science and bio-technology research with the potential of use for purposes prohibited by the Convention.”*⁶

The importance of education and training has been stressed by many other actors. The Organization for the Economic Cooperation and Development (OECD)⁷ called for “*Staff training and developing a biosecurity-conscious culture*” arguing that the “*...creation of a biosecurity-conscious culture in the community are important elements in establishing biosecurity*”. The World Health Organization (WHO) has stated that:

*“...training should help understand the need for protection of ...[Valuable Biological Materials]... and equipment and the rationale for the laboratory biosecurity adopted, and should include a review of relevant national policies and institution-specific procedures ... Should also provide guidance on the implementation of codes of conduct ... [This] training should be offered regularly...”*⁸

In terms of specific biosecurity related education at the academic level, the European Commission’s Green Paper on Biopreparedness of 2007 stated:

³ Language used varies slightly. See UN (2006) “Additional Understandings And Agreements Reached By Review Conferences Relating To Each Article Of The Biological Weapons Convention” [http://www.unog.ch/80256EDD006B8954/\(httpAssets\)/66E5525B50871CAEC1257188003BDDD6/\\$file/BWC_Text_Additional_Understandings.pdf](http://www.unog.ch/80256EDD006B8954/(httpAssets)/66E5525B50871CAEC1257188003BDDD6/$file/BWC_Text_Additional_Understandings.pdf)

⁴ See Statements of, *inter alia*, the UK (2006), Italy (2006) and the Netherlands (2006) “Background Information Document On Compliance By States Parties With Their Obligations Under The Convention” BWC/CONF.VI/INF.6, 20 November 2006. <http://daccess-ods.un.org/TMP/6291119.html>

⁵ UN (2006) “BTWC Sixth Review Conference Final Document”, Geneva, BWC/CONF.VI/6 <http://www.bwpp.org/6RevCon/documents/2006126thRevConfinal.pdf> Page 11

⁶ *Ibid* Page 21

⁷ OECD (2007) “Best Practice Guidelines on Biosecurity for BRCS” <http://www.oecd.org/dataoecd/7/13/38777417.pdf> Page 13

⁸ World Health Organization (2006) “Biorisk Management: laboratory biosecurity guidance.” http://www.who.int/csr/resources/publications/biosafety/WHO_CDS_EPR_2006_6.pdf

“... the goal is to build up a strong culture of awareness and compliance with bio-standards already for first- and second-year life sciences and biotechnology students at university level. Compulsory academic courses in life sciences could focus on dual-use consequences of bio-research. The courses could cover issues such as the risk of misuse of research results in relation to biological terrorism and warfare and professional responsibility as well as liability”⁹

In 2008, the CBRN Task Force of the European Commission recommended the identification, development,

“...and spread good practices on academic training on bio-safety standards and ethics for undergraduate, graduate and postgraduate students; in conjunction with university and professional associations, consider development of minimal requirements for academic training on bio-safety standards and ethics for undergraduate, graduate and postgraduate students”¹⁰

The implementation of such a recommendation, which focuses on education for *undergraduate, graduate and postgraduate students*, would provide several benefits. Firstly, the development of biological weapons is likely to require some degree of scientific capability, particularly with high-end agents such as anthrax and smallpox, and/or more advanced delivery technologies such as aerosolisation or transdermal delivery. The development of such weapons is more likely to involve a degree of sophistication, and as a minimum, this would lead to a primary grouping of individuals trained in the life sciences to at least undergraduate level. This has further advantages in that it is the numerically largest group engaged in specialist study of life sciences. Secondly, a set of minimum requirements within the academic curricula would ensure all life sciences students graduate with at least a basic knowledge of the biosecurity concerns of the security community. Thirdly, it may be easier to instil concepts such as biosecurity and scientific responsibility during a formative academic period, which, notably, already in many cases includes some bioethics related provisions. Cumulatively this could facilitate the creation of a culture of responsibility among the next generation of life scientists that would be self-sustainable and self-promulgating. In this regard, the CBRN Task Force of the European Commission proposal to identify, develop and spread good practices amongst students in university life science education may prove a more effective approach than workplace training and a logical first step in building a culture of responsibility.

Thus, there have been many calls for greater awareness raising and education on the issue of dual-use research and biosecurity, not just in the diplomatic sphere but more broadly from inside the scientific community¹¹ and amongst NGOs, several¹² of which have taken the issue one step further and began the process of developing biosecurity or dual-use educational modules.¹³ Yet, despite such broad support and the activities being carried out amongst the NGO community, it is not clearly established the extent to which these statements have been translated into concrete action at the level of the practising scientist.

The objective of the joint project between the Landau Network-Centro Volta (LNCV) and the Bradford Disarmament Research Centre (BDRC) is threefold. Firstly, it aimed to investigate the extent to which biosecurity education is included in academic curricula in European life sciences higher education and the means and methods through which this is achieved, but also develop an understanding of the attitudes of life scientists and life science educators towards such education. Secondly, engage the academic scientific community in a discussion on contents, delivery and challenges posed by the

⁹ Commission of the European Communities (2007) *“Green Paper on Bio-preparedness”* (5.3: Enhancing Analysis and Security Issues Related to Biological Research) http://eur-lex.europa.eu/LexUriServ/site/en/com/2007/com2007_0399en01.pdf

¹⁰ EC CBRN Task Force BioSubGroup (2008) *“Threats to Human Discussion Paper”* http://www.ebsaweb.eu/ebsa_media/Downloads/EBSAActivities/Biosecurity+and+Bio_preparedness-p-877/Threats+to+humans-p-881/08_08_28_Bio_Humans_prevention.doc Page 5

¹¹ Editorial (2006) *“Dual-use’ biotech - proceed with caution”*, *‘The New Scientist’*, issue 2573, 14 October 2006. Internet resource, available from: <http://www.newscientist.com/channel/opinion/mg19225732.800-editorial-dualuse-biotech--proceed-with-caution.html>; Dando, Pearson, Rozsa, Robinson and Wheelis (2006) *“Analysis and Implications”*, *‘Deadly Cultures’*, London, Harvard University Press. Pg 373.

¹² See for example those NGO activities listed in text by Brian Rappert, Marie Chevrier and Malcolm Dando (2006) *“In-Depth Implementation of the Btwc: Education and Outreach”* http://www.brad.ac.uk/acad/sbtwc/briefing/RCP_18.pdf

¹³ See section *“Further sources of information”* in this paper.

implementation of education on biosecurity. Thirdly, design pilot educational materials and test such material in the lecture theatre, in the process broadening and deepening a network comprising of both the security and the academic communities.

3. LNCV-BDRC Investigation Background

The aims of the LNCV-BDRC investigation were to assess the extent to which biosecurity education is included in academic curricula in European life sciences higher education and the means and methods through which this is achieved, and to provide information on the attitudes of life science educators towards such education. The investigation was not exclusively focused on statistic data; however it provides an illustrative picture of biosecurity education and attitudes in Europe. The case of Europe was selected not only for the geographical and social proximity with the two organizers but because although different university systems coexist, there has, to some extent, been a harmonization and integration process in academia across the region and interaction between the academic communities of different countries is extensive. Furthermore, there have been institutional proposals for the introduction of mandatory biosecurity education within the academic curricula of life science courses in the region. In order to achieve the objectives outlined above, the investigation was initially orientated towards answering the following key questions within the European context:

1. Are there any **biosecurity modules** within the sample life science degree courses taught at the Universities identified? If so, what material is provided, if not, why not?
2. Are there any **bioethics modules** within the sample life science degree courses taught at the Universities identified? Is there any Biosecurity and/or dual-use content within the bioethics modules? If so, what material is provided, if not, why not?
3. Are there any **biosafety modules** within life science degree courses taught at the Universities identified? Is there any Biosecurity and/or dual-use content within the biosafety modules? If so, what material is provided, if not, why not?

The research also aimed to answer the following more specific questions within the context of European higher education:

4. Within the sample life science degree courses in the Universities identified, are there any references to concerns over "**dual-use**"? E.g. are students made aware of, for instance, the concerns that arose from the Mousepox IL-4 synthesis or Spanish flu experiments? If so, what material is provided, if not, why not?
5. Within the sample life science degree courses in the Universities identified, are there any references to the **Biological and Toxin Weapons Convention (BTWC)**, other relevant **Arms Control/Disarmament Agreements** and/or **biological weapons**? E.g. are students made aware of the existence of the BTWC or key aspects of the history of biological weapons? If so, what material is provided, if not, why not?
6. Within the sample life science degree courses in the Universities identified, are there any references to **Codes of conduct/ethics/practice**? E.g. are students made aware of the Inter Academy Panel's "statement of principles" for instance? If so, what material is provided, if not, why not?

The focus on these six different concepts – biosecurity, dual-use, bioethics, biosafety, arms control and codes – was considered important because of the mutually reinforcing nature of these components in forming part of what has been termed a "web of prevention". Clearly, there are other elements that could be included in the search term selection, for example, an explicit search for any export control related content within life science degree courses may prove useful. However, with limited time and a more specific focus on biosecurity - including "transfer security" - we settled on these six focus points which are discussed below.

3.1 Biosecurity

The inclusion of biosecurity content within life science degree courses is an important means of ensuring that life scientists are cognisant of the concerns of the security community. In turn, this can facilitate more effective biosecurity strategies, including the physical security of pathogens, and mitigating any possible resistance from life scientists. Indeed, Sandia National Laboratories have suggested that “[o]ne of the most significant obstacles [to achieving biosecurity] is overcoming the impression – generally held by bioscience researchers who are not accustomed to security procedures – that biosecurity is intrusive, counterproductive, restrictive, or insulting”.¹⁴

3.2 Bioethics

Bioethics covers a broad range of issues. The *Journal of the International Association of Bioethics*, for example, has articles ranging from the “Ethics of Cesarean Section on Maternal Request”¹⁵ to “Is Global Ethics Moral Neo-Colonialism?”¹⁶ Consequently, the relationship between traditional bioethics and contemporary issues such as biosecurity and dual-use is often tenuous. Although bioethics remains a generic concept, there is evidence in the existing literature to suggest that bioethics, or some variant of the term, is a common component of life science courses. For example, in the UK, according to Willmott, a reported 69% of undergraduate programmes “include an ethical component”¹⁷, although Willmott further advises that this figure may not be appropriate to ‘extrapolate nationally’. Nonetheless, an understanding of the relationship between biosecurity and bioethics as well as a statistical data on the existence of such ethics modules provide a useful framework within which biosecurity concerns, specifically those concerning the dual-use problem, can be integrated into academia across Europe.

3.3 Biosafety

In contrast to biosecurity, the concept of biosafety is relatively well established and for “several decades, the WHO has been encouraging countries to implement basic concepts in biosafety”.¹⁸ In this context, an understanding of the extent of biosafety modules and their perceived relationship with biosecurity and bioethics within the context of European academia may prove useful in devising means to promulgate biosecurity related education.

3.4 Dual-use

The concept of dual-use describes the possibility that any technology may be put to a purpose other than that which it was originally intended for.¹⁹ In the BW context, this commonly refers to technologies – as well as agents and expertise – that can be exploited for both benign (peaceful) and malign (aggressive) purposes. Eminent examples of the problem of dual-use include the so-called Jackson *et al*’s ‘Mousepox IL-4’,²⁰ Wein *et al*’s ‘Botulinum in milk’,²¹ the reconstruction of 1918 Spanish Flu²² and various examples of research conducted as part of biodefence programmes. An appreciation of dual-use concerns and an understanding of the ramifications of dual-use experiments, have the potential to contribute to both

¹⁴ Salerno. R (2004) “International Biosecurity Symposium: Securing High Consequence Pathogens and Toxins” Symposium Summary, SANDIA REPORT SAND2004-2109. <http://www.biosecurity.sandia.gov/subpages/pastConf/20032005/securing/01Int-Symposium-Summary-Final.pdf> pg 16

¹⁵ Bergeron. V (2007) “The Ethics of Cesarean Section on Maternal Request: A Feminist Critique of the American College of Obstetricians and Gynecologists’ Position on Patient-Choice Surgery”, *Bioethics* Oct 9 2007 (p 478-487). <http://www.ingentaconnect.com/content/bpl/biot/2007/00000021/00000009/art00003>

¹⁶ Widdows. H (2007) “Is Global Ethics Moral Neo-Colonialism? An Investigation of the Issue in the Context of Bioethics” *Bioethics*, Volume 21 Issue 6, Pages 305 - 353 (July 2007) (p 305-315). <http://www3.interscience.wiley.com/journal/118486408/abstract?CRETRY=1&SRETRY=0>

¹⁷ Willmott. C. J. R (2004) “Teaching Ethics to Bioscience Students – A survey of Undergraduate Provision”, *Bioscience Education Electronic journal* Volume 3 May 2004. Internet resource, available from: <http://www.bioscience.heacademy.ac.uk/journal/vol3/Beej-3-9.pdf>

¹⁸ Atlas. R (2005) “Ensuring Biosecurity and Biosafety through Bopolicy Mechanism”, *Asian Biotechnology and Development Review*, VOL.8 No. 1 pg 127

¹⁹ For more on this see for example McLeish. C (2007) “Reflecting on the Problem of Dual Use” In: Rappert. B & McLeish. C (2007) “A Web of Prevention: Biological Weapons, Life Sciences and the Governance of Research”, Earthscan Publications Ltd.

²⁰ For more details on this experiments see: Mackenzie. D (2003) “US develops lethal new viruses”, *The New Scientist*’ 29 October 2003. Internet resource, available from: <http://www.newscientist.com/article.ns?id=dn4318>

²¹ Mackenzie. D (2005) “Milk supplies at risk from terrorist toxin”, *The New Scientist*’ 29 June 2005. Internet resource, available from: <http://www.newscientist.com/article.ns?id=dn7601>

²² Nature (2005) “Special Report The 1918 flu virus is resurrected”, *Nature* 437, 794-795 (6 October 2005) Published online 5 October 2005 <http://www.nature.com/nature/journal/v437/n7060/full/437794a.html>

developing life scientists' understanding of how their research could be misused but also engendering further informed discussion on drawing the line between legitimate and prohibited life science research.

3.5 Arms Control and Partial Disarmament and Biological Weapons

Arms control and partial disarmament agreements - particularly the Biological and Toxin Weapons Convention (BTWC), the Chemical Weapons Convention (CWC) (which also covers toxins) and the 1925 Geneva Protocol - formalise multicultural norms prohibiting the development, stockpiling, acquisition, obtaining and use²³ of biological and chemical weapons. The BTWC and the CWC are legally binding upon all countries considered in this research. An in-depth understanding of these conventions and the history of biological and chemical warfare is too much to expect in most life science degree courses. Nonetheless, an awareness of the existence of these multilateral conventions and their key principles, as well as of key aspects of biological weapons used in biological warfare and bioterrorism, and an overview of key episodes is important, primarily as a means of teaching students about longstanding multicultural prohibitions on methods of warfare, but also to raise awareness of student's responsibilities under international and national law.

3.6 Code of Conduct

The term 'code of conduct' was conflated with a range of ethical, legal and regulatory documents over the course of the first BTWC intersessional process (2002-2006). Such documents are better understood through the categories of codes of ethics, codes of conduct and codes of practice.²⁴ These different codes serve different purposes and logically, one can assume, produce different effects. Whilst there is great merit to enforceable legally-binding codes, ethical codes should not readily be dismissed, and historical examples of short ethical codes implemented in spoken form, such as the Hippocratic Oath, have a long history in other professions. In 2005, the BTWC States Parties met twice in Expert and State Parties Meetings in Geneva to "discuss and promote common understanding and effective action on... The content, promulgation, and adoption of codes of conduct for scientists".²⁵ The outcome of these meetings embodied in the substantive paragraphs of the Chair's report on the Meeting of States Parties 2005 makes several points, agreed by consensus. Thus, States "agreed on the value of... demonstrating the benefits of codes and encouraging relevant actors to develop codes themselves" and "recognis[ed] that codes of conduct will be most effective if they, and the principles underlying them, are widely known and understood". There have subsequently been several calls for the development of a "code" including several examples from European States.²⁶ In this context, an assessment of the extent to which this has trickled down to the university level may prove useful.

3.7 Sample Selection

The degree course sample used in this research consisted of 142 life science degree courses in Europe; this is based on a general selection criterion of two undergraduate courses and two master courses from 57 universities across Europe. In selecting the life science degree courses used in this sample, several issues were taken into consideration, including course level, course focus and university selection.

²³ Whilst the CWC and the Geneva Protocol explicitly prohibit the use of such weapons, the BTWC has no explicit prohibition on use. However, the BTWC is widely considered by most -not all- states to cover use and any effort to use biological weapons would entail a breach of the prohibition of the conventions central tenets.

²⁴ The former, codes of ethics, are best conceptualised as pithy aspirational codes; 'codes of conduct' can be defined as extended guidance documents; whereas codes of practice should be viewed as legal documents which prescribe the legal responsibilities of the practitioner

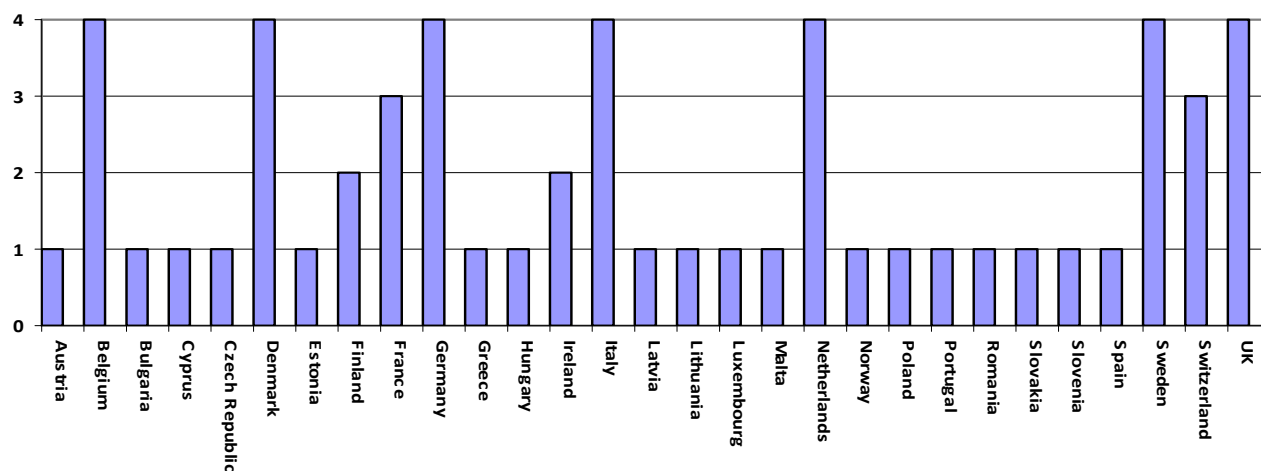
²⁵ UN (2002) "Final Document", *Fifth Review Conference of the States Parties to the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxins Weapons and on their Destruction* Geneva, 19 November - 7 December 2001 and 11 - 22 November 2002. Internet resource, available from: [http://www.opbw.org/rev_cons/5rc/docs/final_dec/BWC-CONF.V-17-\(final_doc\).pdf](http://www.opbw.org/rev_cons/5rc/docs/final_dec/BWC-CONF.V-17-(final_doc).pdf)

²⁶ The Hungarian academy of sciences (HAS) has "initiated consultations" on this issue Hungary (2006) BWC/CONF.VI/INF.6 Page 29; as early as 2002, The Estonian Academy of Sciences adopted a "Code of Ethics of Estonian Scientists" Estonia (2006) BWC/CONF.VI/INF.6 Page 16; In the Netherlands, "As a result of the MSP in 2005, the Royal Academy for Arts and Sciences (KNAW)... will assess the potential contribution of codes of conduct, the content thereof and the promulgation and adoption thereof" The Netherlands (2006) BWC/CONF.VI/INF.6 Page 42 ; Finally, the UK Foreign and Commonwealth Office, "hosted a successful high-level seminar on codes of conduct at which over 70 academic and government scientists discussed fostering a culture where scientists consider the potential for the misuse of their work, issues related to the implementation of codes of conduct and how to pursue them in the future" .UK (2006) "Statement to the 6th Review Conference", [http://www.unog.ch/80256EDD006B8954/\(httpAssets\)/4130622CD93A31B6C125722C004C4C78/\\$file/BWC-6RC-Statement-061120-UK.pdf](http://www.unog.ch/80256EDD006B8954/(httpAssets)/4130622CD93A31B6C125722C004C4C78/$file/BWC-6RC-Statement-061120-UK.pdf)

In terms of the *degree course level*, as noted above we posited that the target of biosecurity education needs to be those with the requisite capabilities to contribute to the development of biological weapons. In addition to the undergraduate courses, however we further decided to investigate master level courses on the assumption that many students working with higher-end agents or on more specialised areas may require further qualifications in a highly competitive market. In terms of *degree course*, there exists a broad range of courses encompassed under the rubric of the “life sciences”, with many of the universities in our sample offering several different courses. Complete coverage of all the courses offered would have involved a study of several hundred courses and thus was beyond the scope of this research. Accordingly, where possible, we selected two courses: one containing a significant element of practical knowledge and laboratory training that could conceivably be misapplied – such as microbiology or molecular biology; and a second course containing an applied technological component, such as “biotechnology” or “industrial biology”. In practice, the application of the matrix was not always possible.

In terms of identifying the *universities*, the development of the sample used in this composition required generating a balance between, on the one hand, the leading European institutes and, on the other hand, identifying a sample which was, if not representative, inclusive of all European Union member States as well as Norway and Switzerland. There are established ranking systems used by the EU²⁷ to identify leading universities and although there are differences in methodologies and criterion for assessment many of the leading universities identified remain similar. We used this ranking system to

Fig 2. Universities investigated per European country



create a large list of leading European universities. Whilst purportedly indicative of the best universities within the EU (in addition to three from Switzerland and one from Norway), the sample remained unevenly distributed with some states dominating the list. Accordingly, we selected a maximum of four universities from the highest ranked ones from each country to be included in the sample. Furthermore, in order to represent the European Union Member States as broadly as possible, universities that did not appear in the above rankings, but that represented European Countries not listed, were added where possible. In some cases, continental and national rankings were used to identify the best university or

²⁷ In terms of identifying the leading universities in Europe, the EC working Document, Progress towards the Lisbon Objectives in Education and Training, states that: “There are currently two worldwide university rankings: the Academic Ranking of World Universities (ARWU) from Shanghai’s Jiao Tong University, released for the first time in 2003 ... and the World University Ranking (WUR) from the Times Higher Education Supplement (THES)...” Commission of the European communities (2007) “Progress towards the Lisbon objectives education and training Indicators and Benchmarks” Commission Staff Working Document 2007. http://ec.europa.eu/education/policies/2010/doc/progress06/report_en.pdf pg 141

life science departments within the country. It is also notable that to ensure regional (geographic) representation both Norwegian and Swiss institutes are included on the assumption that they contribute to the European academic environment despite not being members of the European Union. This criterion produced a list of 57 universities distributed across 29 European States. These are indicated in figure two.

3.8 Methods

To achieve the objectives outlined above using this sampling approach, we employed two methods of data collection: firstly, we investigated the online course details of selected degree courses in those European universities included in our sample, specifically looking for material dealing with biosecurity, dual-use, bioethics, biosafety, arms control and codes.²⁸ Subsequently, we followed up the online investigation with electronic correspondence or in some cases telephone based, semi-structured interviews; these were primarily designed to achieve three goals:

- 1) Confirm/develop our online investigatory results and provide a basis for discussion;
- 2) Develop and understanding of contemporary attitudes to the teaching of biosecurity and/or dual-use components within life science degree courses in the EU; and
- 3) Elicit an understanding of the reasoning for including *or* excluding these topics.

The targets of our correspondence were primarily degree course coordinators and professors of bioethics courses who were considered more likely to be aware of the biosecurity related content within degree courses. This process of data collection produced both quantitative and qualitative material. The quantitative data derived from the “yes/no” questions was analysed using the electronic statistical software package SPSS. The qualitative data, derived from more open ended questions seeking to elicit an understanding of attitudes, was analysed to determine specific trends and themes in the responses of participants.

4. LNCV-BDRC Investigation Results

Using the methodology outlined above we were able to access life science degree course content for a significant majority of the courses selected in the investigation. More detailed content was often only available in the source language, however, through the use of translation software, it was possible to look through *content* in some 20 languages and develop an understanding of the substance of degree courses, if not specific nuances. There were, however, some degree courses where access was locked or available only for faculty members, in which case we devised the category “Not available”. In terms of the level of participation in the second phase of research (the email and phone contacts), responses to the email questions sent out were limited, with only 47 of the estimated 300 individuals contacted responding to either the first or second emails sent out, or, in some cases, a follow up phone call.

Several factors account for this 16% response rate, not least of which is the fact that the questions were primarily in English, which in many cases was not the participants' first or second language. However, other factors are likely to be uncertainty, particularly in regard to the specific nature and content of degree courses and thus a reluctance to make claims over content - something which became apparent in follow up phone calls - and ultimately, a limited understanding of, and/or interest in, the issue of biosecurity education. The latter point was neatly summarised by one respondent who stated “this is not my ‘cup of tea’”.

In this context, there are clear limitations to the material collected. Nonetheless, based on the qualitative and quantitative material collected in both phases of the study, it is possible to posit several findings. In terms of quantitative results, these are categorised under the headings “Yes”, “No”, “Unclear” and “Not available”. These categories are outlined in figure 3.

²⁸ The online materials investigated referred to the academic year 2007-2008, or to the provisional programs for the academic year 2008-2009

Fig 3. Categories of qualitative results

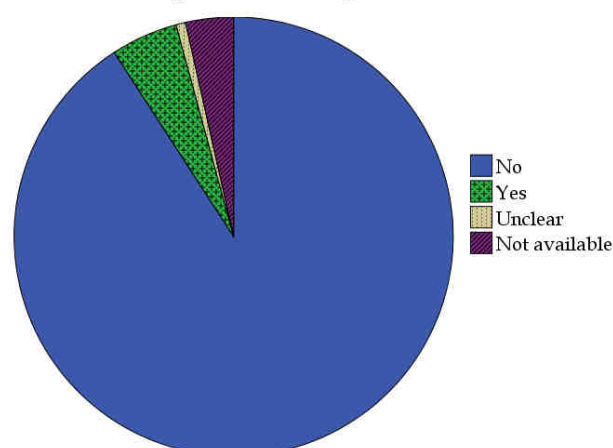
Term	Description
Yes	Refers to data where we can say with a degree of certainty that X is present.
No	Refers to data where we can say with a degree of certainty that X is NOT present.
Unclear	Refers to data where there is some information available but we cannot say <i>with certainty</i> whether X exists or not.
Not available	Refers to data where there are significant constraints upon access to information.

Principle amongst such findings is the limited number of biosecurity modules across Europe, with only three universities offering a specific module and in all cases this was an optional or elective course for students. There are several references to issues of biosecurity, the BTWC and dual-use. However, these are often treated as a minimal part of a general course. In contrast, many universities highlight the importance of ethical content and social responsibility in the overview of their degree courses, but it is not always clear how these issues are delivered to the students. It is important to note that, whilst only representative of a small fraction of the sample, there actually exist some exemplary cases of universities, or singular professors, which are particularly aware and engaged in issues of biosecurity, biological weapons, biological warfare and dual-use and deal with these topics in some depth. A more detailed overview of the results is below.

4.1 Biosecurity

The research suggests that only three universities in our sample - Jagiellonian University (Poland), Uppsala University (Sweden) and University of Vienna (Austria) - currently offered some form of specific biosecurity module. In the case of Poland, module "BT259 infectious diseases, biological weapons and bioterrorism" is a 30-hour course dealing with the history of bioterrorism, key agents that have been used in incidents of bioterrorism and "current threats and methods against them". This course is, however, one of more than 150 modules offered in biotechnology and biology undergraduate courses in Jagiellonian University.²⁹ In the case of Uppsala, correspondence suggested that there were three to five modules "depending on what topic the students focus on" concerning biosecurity. However, such modules were short "usually 2-4 hours per course". Based on broader correspondence, it became clear that at the University of Vienna, a biosecurity module has been developed by one individual who outlined his personal experience in weapons inspection and subsequently discussed, *inter alia*, the "the role researchers played in ... [the Iraqi] ... programme" and arms control measures such as the BTWC. Thus, from our sample of 142 life science courses, only seven life science degrees currently offer such a specific module in the three universities and all these modules appear to be optional.

Fig 4. Biosecurity Module



Qualitative results suggest that one of the reasons for the limited number of biosecurity modules is the constraints placed upon teaching in terms of time. Thus one respondent suggested "the main reason [for not having a specific biosecurity module] being the limited time we have to expose our students to science & society issues". Similar sentiments were expressed by several other respondents and this suggests that consideration needs to be given with regard to the length of time any biosecurity module would take and how such a course can be practically implemented in a competitive degree course market, particularly if the objective is to make such a module compulsory for life scientists. It was

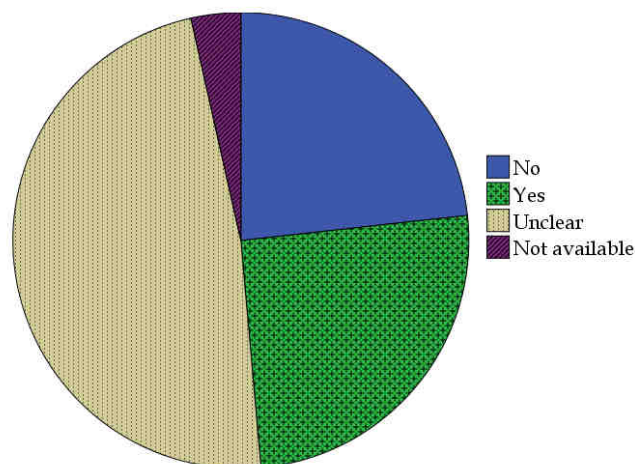
²⁹ See material available from http://biotka.mol.uj.edu.pl/new_www/pdf/kurs-in.pdf pg 87

further suggested that careful consideration would need to be given to the construction and implementation of any such course:

“A special course of biosecurity would be useful to be implemented as a joint course at the University to cover the very broad areas of technology covered by this university. Such a course could also be very important for Ph.D.-students. However, the strategy of delivery of information in such a course should be well planned. Some students clearly become very worried and frightened and, on the other hand, there is always a risk (even if only theoretical) of misuse of the information.”

There was more success in terms of biosecurity “references” and, based on our definition from an arms control perspective, we found a total of 37 life science degree courses out of our sample of 142 where there was clear evidence of a reference to biosecurity. Nevertheless, correspondence with participants and further research suggests that 33 of the total 142 degree courses in the sample did not appear to make a reference to biosecurity. Moreover, because “references” can be both verbal and written and detailed course structures are often unavailable, a significant percentage of degree course content was indeterminable with any degree of certainty and thus unclear or in some cases not available.

Fig 5. Biosecurity Reference



In cases where the evidence pointed towards a reference to biosecurity, the location of such a reference varied. In one case, a biosecurity reference was located in a specific module such as “*guerre, paix et développement*” (War, Peace and Development). In another case, biosecurity “issues are discussed and presented in the basic Microbiology course”, and in yet other cases, biosecurity was discussed in modules dealing with recombinant DNA technology. Largely, however biosecurity references were located within some form of bioethics module.

Moreover, exactly what constituted a “reference” varied considerably. Thus, in some cases a reference constituted biosecurity being “mentioned in some courses – typically during a lecture”, “we touch upon biosecurity” or “Yes but very basic”. Other commentators appeared somewhat guarded in response to questions over biosecurity. Thus one correspondent suggested that:

“There isn't any specific reference to biosecurity as defined in your letter. There are references to what we understand are positive uses of bioresearch. Some of the courses include discussions about applications and implications of biological research and biotechnology in society, and these courses highlight the positive contributions that new technologies offer in a broad range of fields, from medicine to environmental science to forensics.”

Whereas a participant from one of the leading universities in Europe stated that:

“There is no research going on within the Department related to biosecurity or with a potential biosecurity risk. Thus, the focus is on biohazards and the general ethics of research. If there was reason within the aims of the course to refer to research with biosecurity implications, then we would feel obliged to also present those implications and discuss the issues around them.”

There were some grounds for optimism regarding biosecurity. One participant suggested that “Biosecurity issues are discussed and presented in the basic Microbiology course, where 2 lectures specifically address a) microbial hazards with reference to biosecurity b) international treaties on biosecurity and their implementation.” Another participant stated there was a biosecurity reference,

adding that “The Royal Academy of Sciences (KNAW) in the Netherlands has a project on Biosecurity and dual use”. Yet another correspondent suggested that:

“biosecurity takes about three units (each 45 minutes) it might be too long, but I recognized that students find it quite interesting to hear about real stories that I had been involved and shows them that it is in no way a theoretical and abstract subject. So as an entry to the subject I spend about 45 minutes talking about my personal experiences in Iraq where I had spent a few years of my life looking for biological weapons, it starts with a historic background and then focuses on the role researchers played in this programme, it also gives me an opportunity at the end of this 45 minutes to shift over to other types (than UNSCRs) of legal instruments related to BW (Conventions, Australia Group, National and EU legislation, ethics guidelines).”

This latter example is extraordinary and such detailed coverage appears the exception rather than the norm.

4.2 Bioethics Module

In contrast with biosecurity modules, there is evidence of a considerable number of bioethics modules within life science courses across Europe and nearly half of the degree programmes surveyed evidenced some form of bioethical focussed module. Several participants suggesting bioethics was embedded within the curriculum at both levels.

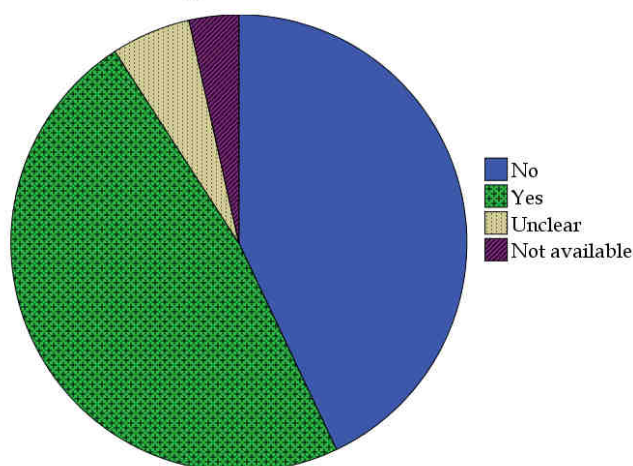
Such modules cover a wide range of issues and are taught by lecturers from a range of backgrounds (law, life sciences, philosophy or ethics). In some cases, the respondents suggested that they try to teach students a ‘method’ for bioethical decision-making, thus trying to instil students with a broader view without going into detail on the multiple ethical issues they may have to face. Beyond this generic ‘method’ or framework approach, based on the research conducted, the following examples are indicative of the breadth of topics covered in such ethical modules: freedom, responsibility, concepts of moral action; “good and evil”; “Questions of Religious Sciences”; “the use and collection of DNA/RNA data”; “the role of science in society”; “ethical and political aspects of biological research”; “Intellectual property”; “Developmental issues”; “theories about the unintended social effects of biomedical technology”; “stem cell research”; and “Ethics of Animal/Patient Research”. This broad range of issues under the umbrella of bioethics suggests that new issues will have to compete for inclusion in bioethics courses.

Fig 7. Bioethics Modules by level

Bioethics Module			
	Masters	Undergrad	Total
No	33	28	61
Yes	28	40	68
Unclear	5	3	8
Not available	3	2	5
Total	69	73	142

In terms of distribution between undergraduate and postgraduate level, 40 out of 73 undergraduate degrees had some form of bioethics module which was in many cases compulsory, whereas 28 out of 69 postgraduate degrees exhibited some form of bioethics module. This issue of timing is significant in

Fig 6. Bioethics Module



terms of developing some form of biosecurity reference, for example, first years may not be able to fully understand such consideration because of the absence of scientific skills at this early stage.

Although the breadth of issues covered under the umbrella of bioethics remains large, the fact that the subject is prevalent in life science courses suggests that through a modest extension of such modules, biosecurity concerns could be inserted either as a sub-module or as a short series of lectures within a bioethics module. In order to achieve this, however, there needs to be both an incentive to include these issues in the curriculum and adequate provision of materials available to ensure informed teaching of this topic.

4.3 Biosafety Module

In terms of biosafety modules, the investigation suggests that 27 of the 142 degree courses in Europe, roughly one fifth of life science degrees in the sample, contain a specific dedicated biosafety module and several of these specific modules were optional. However, this belies the fact that several of the participants posited that basic laboratory training was embedded within other modules.

Such courses are evenly distributed between undergraduate and post graduate levels. Various elements fall under the content of such modules, examples include “Science of Risk and Safety in Chemistry and Biotechnology”; “Understanding of the safety regulations in a bioscience laboratory”; “emergency procedures, environmental, fire safety etc”; “basic aspects of contamination, infection and prevention”;³⁰ and “the safety requirements for working in chemical and biological laboratories”.³¹

Fig 9. Biosafety Modules by level

Biosafety Module			
	Masters	Undergrad	Total
No	43	45	88
Yes	13	14	27
Unclear	10	12	22
Not available	3	2	5
Total	69	73	142

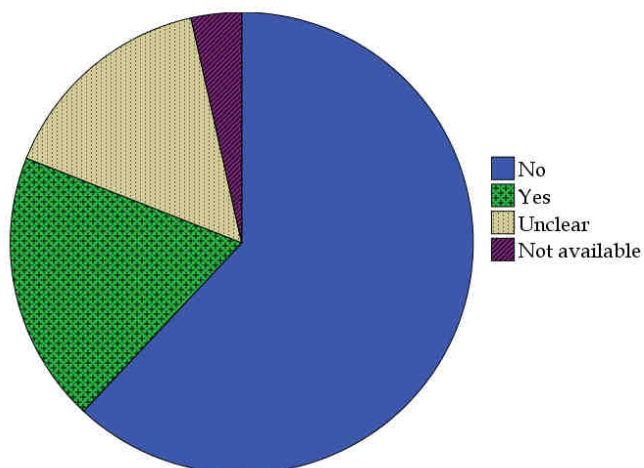
Based on the initial investigation and further correspondence with participants, it remains probable that practical biosafety training varies across the EU both in terms of standards and coverage. Several reasons account for such variance. Firstly, the disparate nature of laboratory facilities means a disparate level of applied biosafety proficiency. Secondly, the absence of accessible laboratory space for students to undertake practical work suggests that in some institutes “training is rather theoretical” whereas in other facilities Good Laboratory Practice (GLP) standards are employed in practical training. In between these poles, some universities, whilst aspiring to GLP standards are likely to struggle to maintain such high standards when dealing with a large volume – in the hundreds in some cases – of students undertaking practical work.

³⁰ See the link for more details <http://www.unimaas.nl/bestand.asp?id=8706>

³¹ See the link for more details

http://66.102.9.104/translate_c?hl=en&langpair=auto|en&u=http://studiegids.uva.nl/web/uva/2007_2008/nl/c/8606.html&tbb=1&usg=ALkIrhgKRvHjLslj_dOULDKt0Iyimh3Xxg

Fig 8. Biosafety Module



4.4 BTWC / Arms Control and/or Biological Weapons Reference

Based on the research conducted, it appears that only a minority of the courses in the study – a total of 22 – made a reference to the BTWC, BW and/or arms control, whereas a nearly a third reported that they did not discuss the BTWC, Arms Control and/or Biological Weapons. Furthermore, exactly what constituted a reference varied, in some cases “It is mentioned in some course(s) – typically during a lecture” or a reference was “embedded in the subjects.”

Indeed, based on the correspondence, it can be suggested that teaching these issues is not common, and in cases where such topics are taught there are normally singular conditions. Thus one degree course in which these topics

were discussed was linked to a foundation for peace studies; in another the course was taught by a former weapons inspector, whereas two other courses which made reference to these issues were a product of national project which covered issues such as the BTWC, as was the case in the Netherlands and Sweden.³² In the remaining cases, the BTWC and Arms control related issues were referred to either in textbooks for the course (for example in the *Introduction to Biotechnology* by Thieman and Palladino³³ or in an Italian bioethics textbook³⁴) or otherwise mentioned by the lecturer.

In terms of the specific nature of teaching on these issues, several courses exhibited a bioterrorism-focused approach. A Swedish-based respondent claimed “We do discuss bioterrorism in the first course and refer to the Swedish systems of control; SMI and FOI as well as some materials from American CDC”. Other courses discussed bioterrorism, biological weapons *and* international arms control agreements, in Poland, for example, one module deals with what has been translated as:

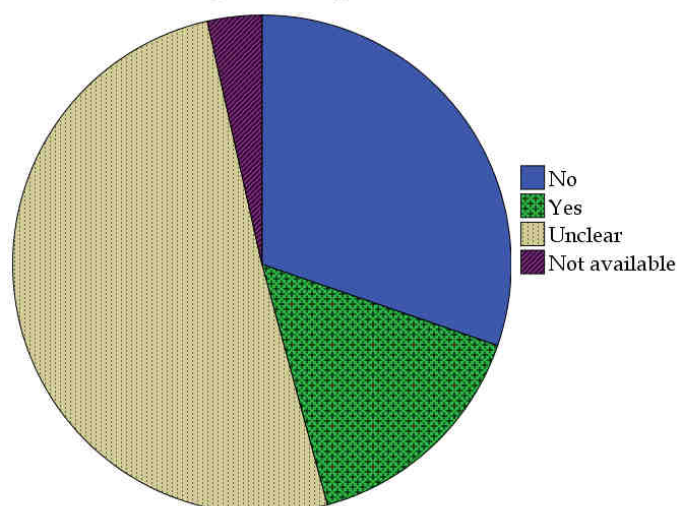
“The essence of bioterrorism. The history of the application [of] biological weapons. The breakdown of biological agents, which can be used as a biological weapon... Hazards related to viral infection... Preservation, sustainability and the means of factors constituting biohazard. Organizations in the fight against terrorism, acts linked to the control and elimination of biological weapons.”³⁵

Yet other courses provided an approach more closely focused on State biological weapons programmes and national legislation:

“... the Iraqi BW programme is briefly discussed, the BTWC is discussed in context of national legislation resulting from the implementation of the BTWC, the CWC is discussed briefly in the context of chemical safety and export-import control.”

From the responses received which indicated they did not make a reference to the BTWC or biological weapons or arms control, the qualitative elaboration on these issues varied. Thus some respondents indicated reluctance to engage in such topics, as one commentator suggested, “we do not teach anything to do with the BTWC. I’m not sure if teaching such material on the BTWC would be helpful to our students unless they went into the field”. Others were more supportive of such an inclusion and indeed

Fig 10. BTWC / Arms Control and/or Biological Weapons Reference



³² Correspondent suggested that “The Royal Academy of Sciences (KNAW) in the Netherlands has a project on Biosecurity and dual use... [specifically on the BW question]... The KNAW has a project running and the provide us with a lot of information”.

³³ Thieman W.J and Palladino M (2008), “*Introduction to Biotechnology*”, Chapter 13: *Ethics and Biotechnology*”, Pearson Benjamin Cummings, 2008

³⁴ Tallacchini M. C., Terragni F. (2004), “*Le biotecnologie. Aspetti etici, sociali e ambientali*”, Chapter 9: *Le Armi Biologiche*, B. Mondadori, Campus, 2004

³⁵ Approximate translation “BT259 infectious diseases, biological weapons and bioterrorism” see the following link for details in Polish. http://biotka.mol.uj.edu.pl/new_www/pdf/kurs-in.pdf pg 87

one participant replied to our question over the existence of BTWC / Arms Control and Biological Weapons Reference by stating “No, but I will take profit of your enquiry and integrate these issues in the introductory course starting with this year”.

4.5 Dual-use

In terms of references to dual-use, 29 degree courses exhibited some reference to the dual-use issue whereas 33 courses did not appear to make any reference to this topic. Information for over half of the courses was unclear or unavailable, thus based on degree courses where information is available, just under half of the courses samples indicated they made reference to the issue of dual-use.

In terms of where and when such a reference was made the specifics varied. In some cases a discussion was embedded in science focused modules such as the “basic microbiology course” in other cases this was part of a bioethics module or some form of “ethics and technology” or “history of science” module. In terms of what level these references were targeted at, 17 of the 29 positive responses were within undergraduate degree programmes.

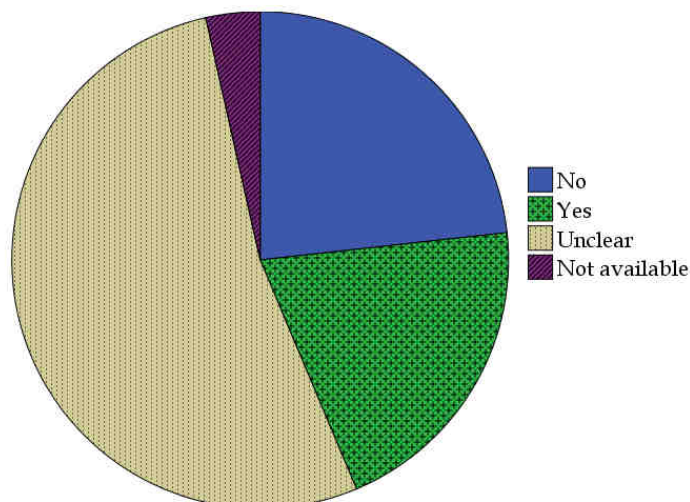
In terms of responses to the notion of dual-use being included within life science degrees, attitudes varied. On the one hand several respondents were very positive about this issue stating: “Yes, it is an area where very limited awareness among students and faculty exists”; “Candidates should be aware of these subjects but I don’t think it can fill out a full course”; “At the level of specific exercises or lectures, probably yes.”; “I think we need to bring it up at more than what we do, since it probably is not brought up more than a few occasions during the five year programme, maybe suggest/offer a bioethics course to the student”.

On the other hand, a smaller number of respondents were more critical often expressing concerns over the space and time for such a discussion. Thus participants suggested “Only to a certain extent, and depending on the required time and resources”; “This is a difficult question to answer. All knowledge is useful. It is a matter of priorities and of limited number of credits/programme”. Notably a few other responses were more forceful suggesting “not at this time” and, in one cases, “dual use? well, I don't know how far this is serious”. Notwithstanding these latter concerns, it becomes apparent that there is some interest in incorporating these issues into the curriculum; however, once again any measures through which this could be achieved would need to be optimised to satisfy concerns over limited space and time within life science degree courses.

4.6 Codes of Conduct/Practice/Ethics

In terms of references to codes of conduct, practice and/or ethics, 31 life science degrees revealed they made reference to some form of code whereas 30 did not. Because of the difficulties in accessing and accurately assessing the full scope of the course material, material dealing with 81 degree courses was not available or unclear.

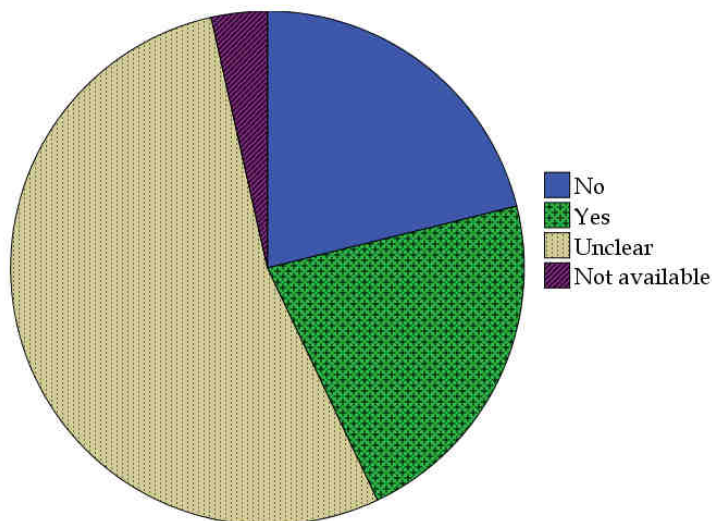
Fig 11. Dual-use Reference



In terms of the location of such references this varied considerably. In some cases these were “integrated into a broader framework course” or taught in specific modules such as “regulations in biotechnology”, “ethics and engineering”, or as “part of the laboratory work education, specifically when dealing with bacteria and viruses”. There was also a degree of variation in terms of what type of code was discussed, with some degree courses focusing on more formalised codes i.e. the ‘European codes of conduct’, the Helsinki declaration or in one case, the Dutch Code, regarding which one commentator stated:

Royal Academy of Sciences (KNAW) in the Netherlands has a project on Biosecurity and dual use. The international code of conduct will be introduced in The Netherlands this year. The KNAW produces information... and is formulating a strategy on how to implement this code of conduct. However, this is a national project and is not a part of a university course yet.

Fig 12. Codes Reference



Other participants pointed to less formalised, more ethically orientated material, thus one participant suggested their reference to codes was “More to a personal code than to a written code”. Yet others focused on codes more in terms of animal experimentation, GMOs or Stems Cells. Indeed, in response to the question do you make reference to codes one participant posited: “Yes, mainly discussing the regulation of the national committee for Life Sciences which is supporting national policies in the field. Unfortunately this platform is too oriented towards health/hot topics as stem cells, etc.”

5. LNCV Workshop and Roundtable

The Workshop and Round Table on “Fostering the Biosecurity Norm: An Educational Module for Life Sciences Students” took place in Como, in the Council Room of the Town Hall of the City of Como, on October 27th, 2008. The Scientific Organizing Committee included the IWG-LNCV and the BDRC, and the Landau Network-Centro Volta Secretariat provided the logistical organization. The meeting was organized thanks to the support of the Italian Ministry of Foreign Affairs, the US Civilian Research and Development Foundation, the International Science and Technology Center, the Lombardy Region and the Municipality of Como. The aim of the workshop was to bring together experts, officials participating in their personal capacity, and importantly representatives of the scientific academic community - including professors and course coordinators involved in life science academic education - to discuss the introduction and/or development of biosecurity considerations within the life science academic curricula.



5.1 Round Table

The first session was designed to frame the issue of biosecurity education and to identify positive and proactive means by which biosecurity related education could be developed in life sciences academic

curricula. After the welcome addresses of the organizers, the first speakers were the representative of the European Commission Directorate-General for Health and Consumer Protection (DG SANCO) and the Chairman of the 2008 BTWC Meetings. The institutional representatives underlined the importance of discussing the issue of biosecurity education for the next generation of life scientists and devising a roadmap for implementation. The Chairman of the BTWC also presented the outcomes of the Meeting of Experts of the BTWC held in August 2008, and the work of the Convention's Implementation Support Unit (ISU). Subsequently, participants outlined the issues that need to be considered, such as: Who needs to be educated? What should be the contents of biosecurity related education? How can biosecurity related education be most effectively delivered? At what level should such education take place? Who should be the educator? And what challenges can be envisaged in efforts to implement biosecurity education?

This was followed by a situational analysis of existing biosecurity related education provision around the world. Although some participants felt that the life science community has come a long way in certain regions, it was broadly recognised that there remains much more to be done and that there is very limited educational material on biosecurity, dual-use and biological weapons in existing life sciences academic curricula. It was further recognised that the advance and expansion of biotechnology widens the problem of dual-use, thus making the development of biosecurity related education an increasingly urgent aspect of biosecurity. This was followed by a productive exchange on the challenges of implementation of biosecurity education and possible strategies to overcome such challenges and move forward.

5.2 Contents of Education

One topic of discussion during the workshop was the contents of biosecurity education. In this regard, whilst recognising that "no one size fits all", there was some agreement amongst the participants that the education should include material on the Biological and Toxin Weapons Convention and national regulations; the history of biological warfare and the role of scientists in past programmes; and the dual-use dilemma. Whilst it would be too much to expect students to study the BWTC in any depth, material on the BTWC and national measures taken in accordance with Article IV - which deals with national implementation -, is clearly of importance in generating an understanding of the international and national prohibitions on biological weapons and how such measures form a "web of prevention". However, it was further posited that it would be useful to provide material on historical incidence of biological weapons programmes and the role of scientists within such programmes, as this would help in generating an understanding of the role and responsibility of scientists. Inextricably linked to this, material on the dual-use dilemma would be useful in explaining the potentially malign consequences of some experiments, such as Mousepox IL-4 and 1918 Spanish flu reconstruction. It was further suggested that such discussion may prove particularly engaging and contemporary and consequently, would likely catch the attention of students.

5.3 Curricular intervention points

A second area of discussion was how to deliver biosecurity related education to life scientists. It was clear from discussion that there is great merit to including "traditional" approaches to education, such as lectures covering the content identified above in conjunction with an essay writing approach to concretise taught material and stimulate further independent thinking. However, it was also posited that there are several advantages to adopting a more "interactive" approach. Such an interactive approach could take several forms, for example one participant outlined the advantages to role play exercises as a means of both raising students' attention and explaining the links with their practical work in both the present and the future.

This latter approach was served as an example of 'active learning', an approach that engages the students, making them "think in somebody else's shoes". This may prove advantageous in promoting the development of writing and thinking, but may also be particularly effective in raising interest in issues that are new or uncomfortable for the students. There is also some precedent for this approach

and role playing exercises with life sciences students on dual-use have been developed and tested by Marie Chevrier, Malcolm Dando and Brian Rappert. Based on their experience it was suggested that students generally enjoyed the simulation exercise, and while it could be a problem to use role playing if biosecurity and dual-use education was a compulsory element of courses with a large number of students, the simulation technique could still be adapted through smaller breakout groups.

5.4 Target level

In terms of what level is most appropriate to target with biosecurity related educational strategies, the Workshop participants posited that the undergraduate level would be the best option in order to reach the widest number of students, and also recognising that existing bioethics courses or courses with social or other non scientific subjects are more common in the undergraduate degrees. However, it further needs to be kept in mind that students may have an insufficient understanding of science in the early stages of degree courses and this may limit the extent to which some material can be understood and applied. In this regard, it was suggested that it would be ideal to have biosecurity related material revisited as part of the degree process as well as in post graduate degrees.

5.5 Compulsory or Optional Biosecurity Education

Many participants pointed out that in order to have effective and far reaching biosecurity related education, teaching on these issues should be mandatory for all those individuals who could contribute either deliberately or inadvertently to the development of biological weapons. Such an approach would cement biosecurity related education as part of the core, compulsory curriculum and it was suggested by several participants that this represents the most suitable means of embedding biosecurity within the curricula rapidly and widely. However, it was recognised by some participants that compulsory biosecurity related education would be a challenge, not least, because of the increasing number of competing topics that need to be covered in life science education and the limited teaching time available within degree courses. In between these two positions, some participants felt that even if some of the biosecurity, dual-use and biological weapons contents were made optional, as a minimum baseline, the teaching of legal obligations and the prohibitions on biological and toxin weapons must be mandatory.

5.6 Who should be the educator

The professors, course coordinators and other participants largely agreed that the best educator for biosecurity would be a life scientist and this would be particularly important in explaining dual-use issues. However, in order for life scientists - or indeed bioethicists and specialists from other non security related disciplines - to teach this issue, biosecurity related teaching materials are essential and several participants pointed out that the extent, availability, suitability and location of such materials was not entirely clear. In this context, it was suggested that it would be useful to both promote and point interested individuals towards existing online material, such as that developed by the Federation of American Scientists, but also maintain some form of open source website for exchanging educational material. More ambitiously it was posited by one participant that it may be worthwhile establishing an open source clearing house which participants could share teaching materials and lesson plans, as well as exchanging evaluations of teaching material.

6. Next Steps

In terms of the future direction of the joint project, Landau-Bradford proposed to build a collection of biosecurity educational materials which will be freely accessible to life science educators and interested parties. The objective would be to broaden and deepen the network established through the research and the workshop and share resources and experience in order to support the effective implementation of greater biosecurity education. In terms of the Bradford-Landau educational material, the following themes are being developed:

- The Responsibilities of Life Scientists.

- The Dual-Use Dilemma in the Life Sciences- Including material on the Fink Report and the Lemon-Relman Report and cases of dual-use experiment, such as the Mousepox Experiment, the Spanish Flu reconstruction.
- The Threat of Biological Warfare (BW) and Biological Terrorism - Including aspects and episodes of the history of biological weapons, biowarfare and terrorism
- The International Prohibition Regime - Including regulations under the BTWC, CWC, Geneva Protocol and the WHO as well as other organizations, particularly stressing the legal obligations
- National Implementation of the BTWC
- Building an Effective Web of Prevention

However, in order to maximise the potential of such material, sound methodological and ethical components are being developed as well as greater clarification of concepts such as the web of prevention. Such material will be made available from the project website, where, significantly, materials from the meeting are already available. In 2009, this material will be tested at participating universities and it is hoped that feedback from such tests will enable us to develop our materials and sustain interest in this type of education beyond the 2008 meetings.

It would further be interesting to expand the investigation beyond Europe, learning from the experience of the first phase of the research outlined above, and broadening the network on a global level. Although similar research has been conducted in the US, and some of the findings from the European focused investigation can be extrapolated internationally. There is no one size fits all approach and accordingly, gaining an understanding of differences and similarities in national and regional attitudes to biosecurity related education may facilitate the development, promulgation and adoption of this type of education taking into account different cultural perspectives.

7. Conclusions

The changing international context has generated increased interest in biosecurity education. However, based on the research conducted over the course of the LNCV-BDRC investigation on biosecurity education in Europe, the workshop and other sources, it appears that interest has not manifested in significant concrete action at the level of the life science academic community. Indeed, it becomes apparent that very little exists in terms of biosecurity related education. Some exceptional existing cases could be considered as examples or models, but we are far from achieving the necessary levels of biosecurity related education for life sciences students to be able to generate a culture of responsibility.

There are a variety of reasons, identified by participants contacted in the Landau-Bradford project, to account for these limitations in biosecurity related education. Some participants felt such material was irrelevant, others suggested such teaching may serve to unnerve students, yet others were unfamiliar with these issues and thus felt unqualified to teach these topics. However, one repeatedly cited explanation was the growing body of competing topics which life science educators are required to teach in competitive degree courses. This latter point is important when considering the development, promulgation, adoption of biosecurity education and there is a clear need for balance and proportionality. In this regard, it may be more logical to support the integration of biosecurity related education within existing course structures and the prevalence of bioethics modules may prove useful to this end. However, in order for this to be effective, it requires that biosecurity education be a part of the core, compulsory curriculum for life scientists in order to develop a self-sustaining and self-promulgating culture of responsibility.

To achieve this there is a need for the States Parties to the BTWC to make a strong statement recognising the value of compulsory biosecurity education, in accordance with national requirements and circumstances, as making a significant and effective contribution, in conjunction with other measures including national legislation, to combating the present and future threats posed by biological and toxin weapons, as well as by raising awareness of the Convention, and by helping relevant actors to fulfil their legal, regulatory and professional obligations and ethical principles. This could further be reinforced by

agreement on the value of demonstrating the benefits of compulsory biosecurity education and encouraging relevant actors to develop biosecurity education. Indeed, it is notable that in cases where states have taken a lead, there appears to be a heightened sense of awareness of the concerns of the security community.

Whilst there is a clear role for States acting collectively and independently, it is also apparent that there are limits to what can be done at the diplomatic level and building a culture of awareness requires the life science community to more actively engage on the issue of biosecurity. This requires linking together the various initiatives on biosecurity education and related projects and, in this sense, the BTWC Implementation Support Unit could have a role collecting, collating and distributing information on related activities. There is also a clear role for higher educational institutions in making biosecurity related education a requisite for the completion of a degree course. Similarly, research funders could push such education further through making biosecurity related education an essential requirement for funding.

Biosecurity related education is not a silver bullet for ensuring biosecurity, yet it is an important component in the 'web of prevention'. As the life sciences continue to advance, the ability of the scientifically uninitiated to comprehend the ramifications of certain types of research may increasingly be surpassed and nurturing a global sense of responsibility amongst scientists now may pay dividends in ensuring the benign advancement of science and society in the future.

8. Recommendations

Based on the research, it appears that there is still much that needs to be done in terms of biosecurity related education. To achieve this, we argue that what is needed is a State Party-level initiative that emphasises the value of ensuring biosecurity related education for life science students. In this regard, it would be fruitful if the States Parties to the BTWC recognise the value of compulsory biosecurity education, in accordance with national requirements and circumstances, as making a significant and effective contribution, in conjunction with other measures including national legislation, to combating the present and future threats posed by biological and toxin weapons, as well as by raising awareness of the Convention, and by helping relevant actors to fulfil their legal, regulatory and professional obligations and ethical principles. This could further be reinforced by agreement on the value of demonstrating the benefits of compulsory biosecurity education and encouraging relevant actors to develop biosecurity education through the creation of some form of implementation framework.

In looking to the future, it is clear that momentum needs to be sustained through and beyond the BTWC Meeting of States Parties in 2008. There is no one size fits all approach to achieving this and biosecurity education must be compatible with national legislation and regulatory controls as well as differing cultural contexts around the world. However, this does not rule out the possibility of building blocks and resources being developed to support the development, adoption and promulgation of biosecurity education which can facilitate stakeholder development of material, thus allowing scientists a degree of ownership of biosecurity related education. Furthermore, it needs to be kept in mind that life scientists have a growing number of ethical and technical issues to cover in degree courses. Given these multiple issues, it may be better to consider how we can integrate new material dealing with the concerns of the security community into existing course structures - such as bioethics modules which appear prevalent at least in the European context - and make these both part of the core, compulsory curriculum for all life scientists. Such teaching material will need to be easily accessible and flexible in order to be widely integrated into existing structures and educational material needs to be coupled with a clear statement outlining the underlying rationale for biosecurity education.

Annex: Workshop Participants List

- 1) **Ambassador Georgi Avramchev**, Chairman of 2008 Meetings of the Biological Weapons Convention, Geneva, Switzerland
- 2) **Victor Axiak**, Deputy Dean, Faculty of Science; Head, Department of Biology, University of Malta
- 3) **Roberta Ballabio**, Programme Officer, LNCV, Como, Italy
- 4) **Daniela Candia**, President, National Board of Biologists of Italian Universities (CBUI), Italy
- 5) **Marie Isabelle Chevrier**, Professor, School of Economic Political and Policy Sciences, University of Texas, Dallas TX, US
- 6) **Ángeles Cuadrado Ruiz**, Professor, Department of Penal Law, University of Granada, Spain
- 7) **Malcolm Dando**, Professor, Bradford Disarmament Research Centre , Department of Peace Studies, University of Bradford, UK
- 8) **Anna Filchenko**, International Science and Technology Center (ISTC), Moscow, Russia
- 9) **Alastair Hay**, Professor, Molecular Epidemiology Unit, LIGHT Laboratories, School of Medicine University of Leeds, UK
- 10) **Jo Husbands**, The National Academies, Washington DC, US
- 11) **Margareta Krabbe**, Programme Coordinator, Bioinformatics Engineering, Uppsala University, Sweden
- 12) **Filippa Lentzos**, Senior Research Fellow, BIOS Centre, London School of Economics, UK
- 13) **Giulio Mancini**, Research Fellow, LNCV, Como, Italy
- 14) **Maurizio Martellini**, Secretary General, LNCV, and Executive Secretary, IWG, Como, Italy
- 15) **Lorna Miller**, Senior Biological Advisor/Non-Proliferation, UK Defence Science and Technology Laboratory, Salisbury, UK
- 16) **Masamichi Minehata**, University of Bradford, UK
- 17) **Sergey Netesov**, Vice Rector (Research), Novosibirsk State University, Russia
- 18) **Kathryn Nixdorf**, Professor, University of Darmstadt, Germany
- 19) **Jan-Peter Paul**, European Commission, DG SANCO, Brussels, Belgium
- 20) **Brian Rappert**, Department of Sociology & Philosophy, School of Humanities and Social Sciences, University of Exeter, UK
- 21) **James Revill**, Researcher, Bradford Disarmament Research Centre, Department of Peace Studies, University of Bradford, UK
- 22) **Nariyoshi Shinomiya**, National Defense Medical College, Tokyo, Japan
- 23) **Jennifer Sta.Ana**, Scientific Freedom, Responsibility and Law Program, American Association for the Advancements of Science, Washington DC, US
- 24) **Lucilla Tempesti**, Research Fellow, LNCV, Como, Italy
- 25) **Olga Vorontsova**, Deputy Director, Center of International Relations , The Russian Federal Nuclear Center - VNIIEF, Sarov, Russia
- 26) **Simon Whitby**, Director, Bradford Disarmament Research Centre, Department of Peace Studies, University of Bradford, UK
- 27) **Reto Wollenmann**, Counsellor, Permanent Representation of Switzerland to the Conference on Disarmament, Geneva, Switzerland
- 28) **Henk Zandvoort**, Professor, Department of Philosophy, Faculty of TPM, Delft University of Technology, Netherlands

Annex: Workshop Agenda

Monday, October 27th

- 9.15-9.30 *Opening by the IWG Organizers*
Maurizio Martellini, IWG-LNCV, Como, Italy
Malcolm Dando, University of Bradford, UK
Jan-Peter Paul, European Commission, DG SANCO, Brussels, Belgium
- 9.30-10.00 *Education and Awareness Raising in the 2008 Meetings of the BWC*
H.E. Amb. Georgi Avramchev, Chairman of 2008 Meetings of the Biological Weapons Convention
- 10.00-11.30 *Session 1. Introducing and Framing the Issue of Biosecurity Education for Life Sciences Students.*
Chair: Maurizio Martellini, IWG-LNCV, Como, Italy
- *Educating Life Science Students: Key Question* **Filippa Lentzos**, BIOS Centre, London School of Economics, UK
 - *Framing the Issue on Education on Biological Weapons, Biosecurity and Dual-Use* **Brian Rappert**, University of Exeter, UK
 - *The US National Academies and Initiatives on Biosecurity Education* **Jo Husbands**, The National Academies, Washington DC, US
 - *Investigation into the Biosecurity Content of European Life Science Degree Courses IWG-LNCV and Bradford Disarmament Research Centre Project* **Giulio Mancini**, LNCV, Como, Italy & **James Reville**, University of Bradford, UK
- 11.45-13.15 *Session 2. Projects for Education of Life Scientists: Contents of Education and How to Deliver*
Chair: H.E. Amb. Georgi Avramchev, Chairman of 2008 Meetings of the Biological Weapons Convention
- *Biosecurity Education in US Universities* **Jennifer StaAna**, Center for Science, Technology, and Security Policy, American Association for the Advancement of Science, Washington DC, US
 - *The Development of Biosafety, Biosecurity and Bioethics Educational Programs in Leading Universities in Russia* **Sergey Netesov**, Vice Rector (Research), Novosibirsk State University, Russia
 - *Preparing Scientists and Engineers for Social Responsibility* **Henk Zandvoort**, Delft University of Technology, Netherlands
- 14.30-16.00 *Session 2 (continuation). Projects for Education of Life Scientists: Contents of Education and How to Deliver*
Chair: H.E. Amb. Georgi Avramchev, Chairman of 2008 Meetings of the Biological Weapons Convention
- *Developing the Material Required for Mandatory Dual-Use Education of Life Scientists* **Simon Whitby**, University of Bradford, UK & **Nariyoshi Shinomiya**, National Defense Medical College, Tokyo, Japan
 - *The Role Playing Exercise* **Marie Isabelle Chevrier**, University of Texas, Dallas TX, US
 - *An Educational Module for Life Scientists IWG-LNCV and Bradford Disarmament Research Centre Project* **Malcolm Dando**, University of Bradford, UK
- 16.15-17.30 *Session 3. Roundtable Interaction*
Chair: Malcolm Dando, University of Bradford, UK
- 17.30-18.00 *Conclusions and Adjournment*

Further sources of information

- **Landau Network-Centro Volta** "Contributions to the Workshop and Round Table 'Fostering the Biosecurity Norm: An Educational Module for Life Sciences Students' Available at: <http://www.centrovolta.it/landau/2008/11/10/ContributionsToTheWorkshopAndRoundTableFosteringTheBiosecurityNormAnEdu.aspx>
"Science and Technology for Non Proliferation Program"
<http://www.centrovolta.it/landau/StaticPage.aspx?Control=NonProliferation>
- **University of Bradford** "Bradford Project on Strengthening the Biological and Toxin Weapons Convention (BTWC)" <http://www.brad.ac.uk/acad/sbtwc/>
- **Federation of American Scientists** "Case Studies in Dual Use Research" Available at: <http://www.fas.org/biosecurity/education/dualuse/index.html>
- **Southeast Regional Center of Excellence for Emerging Infections and Biodefence** "The Dual Use Dilemma in Biological Research"
http://www.serceb.org/modules/serceb_cores/index.php?id=3
- **Center for Arms Control and Non-Proliferation** "Biosecurity: Risks, Responses, and Responsibilities" <http://politicsandthelifesciences.org/index.html>
- **George Mason University** "Biodefense Graduate Program" <http://pia.gmu.edu/grad/biod>
- **University of California Institute on Global Conflict and Cooperation** "Public Policy and Biological Threats: Training the Next Generation" <http://www-igcc.ucsd.edu/cprograms/PPBT/PPBT.php>
- **International Union of Pure and Applied Chemistry (IUPAC)** "Educational material for raising awareness of the Chemical Weapons Convention and the multiple uses of chemicals"
<http://www.iupac.org/web/ins/2005-029-1-050>
- **MIT Professional Education Programme** "Pandemics and Bioterrorism: From Realistic Threats to Effective Policies" http://web.mit.edu/mitpep/pi/courses/combating_bioterrorism.html
- **Nuclear Threat Initiative** "BW Terrorism Tutorial"
http://www.nti.org/h_learnmore/bwtutorial/index.html

For specific educational material:

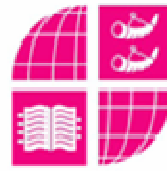
- **Role play exercise material**
<http://projects.exeter.ac.uk/codesofconduct/Publications/Roles.doc>
- **The Life Sciences, Biosecurity, and Dual Use Research Briefing and instructions**
<http://projects.exeter.ac.uk/codesofconduct/BiosecuritySeminar/Education/index.htm>

For general material on Biological weapons and the BTWC:

- **United Nations Office Geneva** <http://www.unog.ch/bwc>
- **CBW Conventions Bulletin** <http://www.sussex.ac.uk/spru/hsp/bulletin.html>
- **University of Bradford Briefing Papers** <http://www.brad.ac.uk/acad/sbtwc/>
- **The Biological and Toxin Weapons Convention (BTWC) website (OPBW)**
<http://www.opbw.org/>



IWG-LNCV



**UNIVERSITY OF
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MAKING KNOWLEDGE WORK

There have been various calls for some form of security orientated education and/or training for life scientists in fora such as the Biological and Toxin Weapons Convention, and there is growing interest in nurturing a culture of responsibility amongst life scientists. This report on biosecurity education was prepared to assist consideration of these issues at the December meeting of States Parties to the BTWC. The report begins by explaining the importance of biosecurity education, particularly for undergraduate life science students. It then proceeds to present the methodology and sampling techniques used in a survey on the extent of biosecurity education in life science degree courses in Europe and the attitudes of life science educators to biosecurity. Using a sample of 142 courses from 57 Universities in 29 countries speaking 25 different languages, we looked for evidence of biosecurity modules, bioethics modules, biosafety modules but also references to biosecurity, the BTWC, BW and/or arms control, dual use and codes of conduct.

This research suggested that only 3 out of 57 universities identified currently offered some form of specific biosecurity module and in all cases this was optional for students. There is evidence of a considerable number of bioethics modules and nearly half of the degree programmes surveyed evidenced some form of bioethical focussed module. In terms of biosafety modules, the investigation suggests that 27 of the 142 degree courses in Europe, roughly one fifth of life science degrees in the sample, contain a specific dedicated biosafety module although several of these specific modules were optional. Exactly what constitutes a reference varies; however, based on the quantitative data from the investigation, we found a total of 37 life science degree courses out of our sample of 142 where there was clear evidence of a reference to biosecurity. Only a minority of the degree courses in the study – a total of 22 out of 142 - made a reference to the BTWC, BW and/or arms control and a similar number, 29 degree courses, exhibited some reference to the dual-use issue whereas 31 life science degrees exhibited some form of reference to a code of conduct.

These results were presented at a Workshop and Round Table held in Como, on October 27th, 2008 in which biosecurity education was discussed with international biosecurity experts and life science lecturers. Many participants agreed that undergraduate level would be the best option in order to reach the widest number of students most effectively and that the educational content should include material on the Biological and Toxin Weapons Convention and national measures; the history of biological warfare and the role of scientists in past programmes; and the dual-use dilemma. It was further suggested that there is great merit to including “traditional” approaches to education, such as lectures, but other approaches may be a useful complement. Significantly, many felt that teaching on these issues should be a mandatory part of the curriculum in order to be most effective, however, it was recognised there may be difficulties in fitting biosecurity content into already busy teaching schedules. It was further recognised by participants that there is a lack of availability and suitability of biosecurity teaching materials for biosecurity education. To this end, the conclusions from the research process suggest that educational material is urgently needed and, on this basis, the next steps of the Landau-Bradford project will focus on the production of draft materials, and on testing their implementation.

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